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Nygaard, Ivan; Andersen, Anette Ester; Larsen, Thomas Hebo; Cronin, Tom; Davis, Neil

Publication date:
2018

Document Version
Publisher's PDF, also known as Version of record

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October 2018

Kenya Miniwind

Vestas | Kenya Climate Innovation Center | DTU Technical University of Denmark | SustainableEnergy | Rural Electrification Authority

Authors

Ivan Nygaard, UNEP DTU Partnership
Anette Andersen, UNEP DTU Partnership
Thomas Hebo Larsen, UNEP DTU Partnership
Tom Cronin, DTU Wind
Neil Davis, DTU Wind

Cover photo:

PowerGen PV mini-grid demo unit, Tom Cronin, 2017

ISBN: 978-87-93458-31-4

This report is issued by the Kenya Miniwind project funded by the Ministry of Foreign Affairs of Denmark through the Danida Market Development Partnerships. The project aims to explore and develop the market for a partly locally produced kW wind turbine to be integrated into a PV mini-grid for rural electrification in order to reduce the cost of electricity and support local value creation.

The long-term objectives of the project are accordingly to contribute to poverty reduction, stimulate economic growth and increase the supply of sustainable energy. The short- to medium-term objective is to explore the market potential and learn more about how to design solutions and business models that are suitable for rural electrification. The project will therefore conduct a market study, engage in dialogue with local communities and authorities, and demonstrate the technical, social and economic feasibility of integrating a kW wind turbine into a smart solar-powered mini-grid in Kenya. The project will also describe the assembly and production of a key component of the demonstration wind turbine. Finally, the project will work to improve the mini-grid developer sector in both Kenya and the wider region. The aim is that the knowledge generated through these activities will help develop the concept into a viable business model for the private companies involved, thus paving the way for the large-scale deployment of rural wind.

The project is a partnership between SustainableEnergy, Vestas Wind Systems A/S, the Technical University of Denmark, the Kenya Climate Innovation Center and the Rural Electrification Authority.

MINISTRY OF FOREIGN AFFAIRS OF DENMARK
DANIDA | INTERNATIONAL DEVELOPMENT COOPERATION

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Abbreviations

CAPEX	Capital Expenditures
DNO	Distribution Network Operator
EEP	Energy and Environment Partnership
EWURA	Energy and Water Utilities Regulatory Authority
kW	Kilowatt
LCOE	Levelized Cost of Electricity
MFP	Multifunctional Platforms
MW	Megawatt
NGO	Non-Governmental Organization
NREP	National Rural Electrification Program
OPEX	Operating Expenses
PIDG	Private Infrastructure Development Group
PSMP	Power Systems Master Plan
PV	Photovoltaic
REA	Rural Energy Agency
REMP	Rural Energy Master Plan
SDG	Sustainable Development Goals
SHS	Solar Home Systems
SPP	Small Power Producers
SPPA	Standardized Power Purchase Agreements
SPPTs	Standardized Power Purchase Tariffs
SWER	Single Wire Earth Return

1. Introduction

The world is currently witnessing a large-scale roll-out of new renewable energy capacity that is contributing to growth and prosperity while also reducing the environmental impact of power generation. Recent years have seen a number of projects with record low prices for utility-scale wind and solar projects across both developed and developing countries. This trend is expected to continue over the coming years, thereby making these renewable energy sources ever more cost-competitive with conventional energy sources in various markets.

However, we still face the challenge of providing power to the 1.1 billion people currently living without electricity (IEA, 2017). The vast majority of this group live in Sub-Saharan Africa and India, with current projections indicating that by 2030 there will still be 700 million people without access to electricity, 90% of them residing in Sub-Saharan Africa (IEA, 2017). These groups typically live in scattered settlements in rural areas and have relatively low levels of income and consumption. This makes the conventional approach to supplying power inappropriate here, since extending the national grid is not economically feasible, given the distance from the grid and the consumption profile of the target consumers.

Instead, the focus has centred on mini-grids as a viable solution for providing these communities with access to energy. Mini-grids of various sizes can connect houses and villages through a grid that is supplied by energy generated on a small scale and on site. Mini-grids have traditionally relied on diesel generators, but more recently solar PV systems that store energy in batteries have been successfully implemented and are currently seen as the least cost option in Kenya.

This project aims to investigate the potential for integrating modern, small-scale wind turbines into solar-powered mini-grids as a way of further reducing the price of electricity in mini-grids. The price of the electricity produced from wind turbines ultimately depends on the wind resources that are available locally and the investment and running costs for the turbine. However, solar and wind energies complement each other because of the different production profiles of the two energy sources over the course of the day. Thus, the value of the wind energy produced can be much higher when the sun is not shining. By demonstrating that small-scale wind turbines can be effectively integrated into solar-powered mini-grids, this project will help develop the market for solutions to the goal of providing electricity that rural residents in developing countries can afford. In turn, providing access to sufficient and reliable electricity will help sustain the productive and income-generating activities of local communities in order to spur growth, create jobs and alleviate poverty in the rural areas of developing countries.

1.1 Market segmentation

Wind turbine manufacturers consider several dimensions when they segment the markets for wind turbines:

- Country-level segmentation of markets
- Pad versus MW constraint markets
- Wind-class segmentation

First, the country-level segmentation looks at legislation and how it is defined nationally, as there may be large differences in terms of grid requirements, noise requirements and bird and wildlife preservation that can affect product development and define the License to Operate in and Enter (LtOE) a given market. Subsequently, a regional segmentation is conducted to account for potential regional differences in legislation within a country.

Second, it is important to understand the limits that different countries have set to the maximum size of large wind-power plants. This is an indicator of whether it is the maximum generating capacity per turbine that is important or the maximizing of the wind-power plant's capacity, based on a given capacity constraint per site.

Third, for each regional or national segmentation, it is vital to have a benchmark understanding of the wind conditions. In the wind industry, most profit will be earned from the highest wind classes, since a high wind-class turbine will generate a higher annual yield than a turbine tailored for a lower wind class.

The above segmentation is not fully applicable to small kW turbines, but in order to remain within this framework, in this report we have used it as a guide in assessing market segmentation.

Country-level segmentation of markets

The project has a regional outlook, and market studies similar to the present one have been published for Kenya and Uganda. The Kenya Miniwind project has a main focus on Kenya because Kenya has a large number of mini-grids already operational, planned or under development. Kenya also has experience with both small- and large-scale wind power, as well as large areas with reasonable wind conditions. It also has an important industrial base and a policy favourable to industrial development. As the production of wind turbines in Kenya would need a regional market to be beneficial, a study of the market for small wind turbines has also been carried out in Tanzania and Uganda.

Pad versus MW constraint markets

This parameter is not directly implementable here, but the size of the turbine to be demonstrated will be decided on the basis of an analysis of the market for different sizes of wind turbines in Kenya and neighbouring countries.

Small wind turbines (10-100 kW) can be connected to the main-grid or to mini-grids. There could be a market for small grid-connected turbines in areas with good wind conditions, but the potential market for them has not been assessed in this report. Any such market will depend strongly on the conditions for net-metering, non-bureaucratic power purchasing agreements and the interest of small investors living close to potential sites for the turbines.

At present, the project's partners are convinced that the market for mini-grids is more viable because mini-grid investors are obliged to invest in production capacity in respect of new or existing grids when demand increases. This means that, if the levelized cost of electricity (LCOE) in the case of wind-produced electricity is competitive with PV-produced electricity in a system using batteries, the mini-grid investor can make the choice to include wind energy in the system. Furthermore, the real value of adding wind may be that additional generating capacity can be added to a system without going to the expense of adding the additional storage capacity necessary if just the solar PV capacity is expanded alone.

The market study has identified all existing and planned mini-grids in Tanzania, including the size of electricity-producing systems, such as PV, diesel, etc., with the objective of providing input into the decision regarding what size of wind turbine to develop in the project.

Wind resource categories
To provide information on this essential parameter, this study divides the planned and existing mini-grids into wind resource categories based on geospatial information regarding the mini-grid locations and on data for annual average wind speeds at 20 m above ground level from the Global Wind Atlas. The sites are divided into 0.5 m/s intervals for wind speeds above 4 m/s.

1.2 Structure of the report

This report is based mainly on a desk study and has benefitted from various sources of knowledge available to the partners. The next section in the report provides an overview of the existing and envisaged policy for rural electrification in Tanzania. Section three provides an overview of existing mini-grids in Tanzania, while section four describes plans for mini-grid development. Section five identifies the public and private market players, while section six provides insights into existing wind-turbine importers, manufacturers and installers. Section seven then links the position of planned and existing mini-grids with the expected wind resource potential and provides a classification of the sites based on wind-speed intervals of 0.5 m/s. Finally, section eight provides a conclusion to the study.

2. Policy framework for rural electrification

The new set of policy, regulatory and financing mechanisms recently implemented in Tanzania represents a recognition of the role of the private sector and of the opportunities to increase and diversify the country's energy supply. The small power producers (SPP) framework addresses some of the previous barriers to accelerating the development of renewable energy mini-grids and their scaling up.

2.1 Existing policy framework

2.1.1 Brief review of the basic policy framework in the most recent period

The first National Energy Policy for Tanzania was formulated in 1992. Rural electrification was made a priority as a result of all regional headquarters having been electrified. The focus was now on the district headquarters, agro-based industries and areas outside economic break-even distances from the grid. In addition, the government established a rural electrification fund (Ministry of Water Energy and Minerals, 1992). At the time of the first National Energy Policy, and until its 2003 revision, the energy sector remained fully under government control (Ministry of Energy and Minerals, 2003). The emphasis in the revised National Energy Policy 2003 was placed on encouraging private-sector participation in the energy sector, including private investments in renewable energy mini-grids by means of a transparent institutional framework and the liberalization of the energy and electricity sector (Ministry of Energy and Minerals, 2003).

In 2005 the Rural Energy Act was established to "*promote rural socioeconomic development by facilitating extended access to modern energy services for the productive economic uses, health and education, clean water, civil security and domestic applications*" (Government of Tanzania 2005). The Rural Energy Act, enacted to deal with rural energy issues, established the Rural Energy Agency (REA) and the Energy and Water Utilities Regulatory Authority (EWURA). The governmental agency REA was to deal with resource mobilization, investments and the promotion of "modern energy", as well as electrification in rural areas. The autonomous authority, EWURA, had the remit to regulate the water and energy sectors. Modern forms of energy[1] were to be promoted by grants and subsidies from the Rural Electrification Fund.

In 2008, Tanzania adopted a new regulatory framework to encourage low-cost investment in mini-grids, called the Small Power Producers (SPP) framework. This was the beginning of a range of new policies to accelerate the development of renewable energy mini-grids and their scaling up.

[1] ''Modern energy'' means energy based on petroleum, electricity or any other forms of energy that have commercialized market channels and a higher heating or energy content value than traditional biomass fuel, and that may be easily transported stored and utilized.

2.1.2 First-generation SPP frameworks, 2008

The first-generation SPP framework was adopted as part of the Electricity Act 2008 in order to encourage low-cost investment in mini-grids. It specified the commercial and legal provisions by outlining a clear process for the initiation, signing and licensing of SPPs under which private-sector participation could contribute to the development of rural energy (Odarno, Sawe, Swai, Katyega, & Lee, 2017). The SPP framework enacted Standardized Power Purchase Agreements (SPPA) for main and mini-grids and incorporated feed-in tariffs (standardized power purchase tariffs [SPPTs] in the Tanzanian context) for SPPs that used renewable energy.

Under this first-generation framework, the financial mechanism created, in the form of SPPTs, was technology-neutral, meaning that tariffs were the same for different technologies. This arrangement tended to favor biomass and hydro development due to the higher costs of solar and wind. The feed-in tariffs a SPP would receive for the sale of electricity differed depending on who the off-taker was: the public utility TANESCO, through either the main grid or isolated mini-grids, or retail customers, or both. However, the feed-in tariff agreement increased the risk for developers and SPPs in cases when a mini-grid connected to the main grid and TANESCO reduced the tariff it paid.

2.1.3 Second-generation SPP frameworks, 2015

In 2015, the first-generation SPP framework was revised so as to encourage greater participation by the private sector and to help support solar and wind mini-grid projects. The second-generation SPP frameworks took into account different renewable technologies, plant sizes and site-specific characteristics, thus providing a more accurate reflection of the cost differences of different technologies. This was meant to increase investment in renewable energy and the deployment of renewable energy technologies by being technology-specific and cost-reflective for projects of up to 10 MW. The revision now covered the development of hydro, biomass, wind and solar energy projects with a capacity range of 100 kW–10 MW (Odarno et al., 2017) using two approaches. The first was to apply renewable energy feed-in tariffs (REFITs) to small renewable-energy projects using hydro, biomass, wind and solar of 0.1–1 MW. Feed-in tariffs are determined by EWURA or set as a 500 kW biomass tariff + 15 percent if connected to isolated mini-grids, or 5 percent if connected to the main grid (Government of Tanzania, 2016). The second approach was to introduce competitive bidding for solar and wind projects with a capacity of 1–10 MW. With the expectation that technological progress will continue to drive down the costs of wind and solar, project- or site-specific competitive bidding processes will determine the SPPTs for 1-10 MW wind and solar projects. Solar or wind projects with a capacity of less than 1 MW are not subject to competitive bidding.

The second-generation framework addresses the previous problem of SPPs receiving lower tariffs upon connection to the main grid by applying the same feed-in tariff independent of the off-taker.

2.1.4 Third-generation SPP frameworks, 2017

The third and most recent generation of the SPP frameworks introduced several significant improvements to create an enabling regulatory environment and address 'grey areas' in the previous SPP Rules. The Electricity (Development of Small Power Projects) Rules of 2017 now: 1) allow mini-grids at multiple locations to acquire a single license (above 1 MW) or registration for mini-grids using the same technology (below 1 MW); 2) provide for provisional registrations for mini-grids; 3) define eligible customers that need not have their tariffs reviewed by EWURA; 4) allow grid-connected mini-grids to operate in islanded mode when the main grid power supply is not available; and 5) provide additional credibility and clarity on the calculation of compensation for distribution assets when the main grid is connected to a previously isolated mini-grid (Government of Tanzania, 2017).

In particular, the new rules are expected to encourage additional investment in mini-grids by addressing important issues such as guidance on options for when the main grid arrives and by simplifying licensing and registration requirements.

2.1.5 Exempting mini-grids from regulatory tariff approval

Tanzania has recognized the opportunities that mini-grids offer and the potential for private-sector engagement by introducing policies and regulations that support mini-grid development (Vinci et al., 2016). As a result, Tanzania has made great progress in developing a comprehensive SPP regulatory system. Under the second-generation frameworks of 2015 in the Government Note: *Electricity (Development of Small Power Project) Rules, 2016*, EWURA sets out the licensing and tariff regulation requirements for mini-grids that have changed this field (Government of Tanzania, 2016). **Very Small Power Producers (VSPPs)**, those with a capacity of less than 100 kW, are exempted from licensing or tariff regulation requirements. No prior regulatory review or approval of proposed retail tariffs is needed, allowing operators to set tariffs in consultation with their local communities. However, if the VSPPs choose to sell to the distribution network operator (DNO), they must follow a specific procedure.[2]

2.2 Challenges and potential changes in the policy and regulatory framework

Many of the policy and regulatory challenges that previously held back the development of mini-grids by SPPs have been successfully addressed since the 2000s and the multiple generation frameworks were introduced. Despite these successes, however,

[2] The relevant procedures are described in the following EWURA documents: 'Standardized Tariff Methodology for the Sale of Electricity to the Main Grid in Tanzania under Standardized Small Power Purchase Agreements' (2008); 'Standardized Tariff Methodology for the Sale of Electricity to the Mini-Grids in Tanzania under Standardized Small Power Purchase Agreements' (2009); 'Guidelines for Development of Small Power Projects' (2011); 'The Standardized Small Power Purchase Tariff for 2014'; 'Detailed Tariff Calculations for Year 2015 for the Sale of Electricity to the Mini-Grids in Tanzania' (2015); and 'The (Revised) Electricity (Development of Small Power Projects) Rules' (2016).

there remain challenges. These mainly involve tariff issues, the insolvency of TANESCO and an over-complicated process of implementation. According to (Odarno et al., 2017) the most important challenges that continue to affect the Policy and Regulatory Frameworks are the following.

Cost-reflective retail tariffs charged by mini-grids and approved by EWURA are still not fully cost-reflective and are significantly higher than TANESCO's cross-subsidized retail tariffs. In 2014 the Ministry of Energy and Minerals developed and began implementing a strategic road map, "Electricity Supply Industry Reform Strategy and Roadmap 2014-2025", to restructure the power sector by unbundling TANESCO (Industry & Strategy, 2014). This was done to attract private investment and participation in the energy sector and in part to improve TANESCO's financial position. However, the feed-in tariff framework has not been so effective in attracting greater interest in mini-grid development due to TANESCO's difficulties in meeting SPPA conditions.

According to (Odarno et al., 2017), the planning process for new mini-grids with a capacity larger than 100 kW is long and complicated, and procedures outside the electricity sector should have been used to streamline licensing and approvals. If the Government of Tanzania were to review and simplify the steps, procedures and requirements involved in the mini-grid development planning process, coordination could be improved.

The lack of easily accessible, comprehensive data on energy resources, funding sources and the operational results of mini-grids has hampered development. According to (Odarno et al., 2017), this could be assessed by adding a database with information on detailed mini-grid characteristics, thus making information about mini-grids available to relevant actors. An obvious site for this content could be the existing mini-grid information portal (mini-grids.go.tz), which currently provides information on licensing and financing and a library containing all the relevant legislature and documents for investors interested in developing renewable mini-grids in Tanzania.

Odarno et al. mention several additional measures when listing priority actions to grow mini-grid technology within the country, namely building up knowledge and developing an adaptive policy and regulatory framework, developing the capacity of mini-grid developers, and constructing a better understanding of the impacts of mini-grids on development efforts in areas like agriculture, health and education.

2.2.1 Summary of frameworks

To sum up, in Tanzania VSPPs with a capacity of less than 100 kW are exempt from licensing or tariff regulation requirements as a result of the second-generation frameworks of 2015. No prior regulatory review or approval of proposed retail tariffs is needed, thus allowing operators to set tariffs in consultation with their local communities.

3. Mini-grid development, including projects under construction

Rural electrification is a priority for the Tanzanian government in order to accelerate economic and social development. However, extension of the national grid to the many isolated areas of the country is less economically feasible than off-grid solutions in the short or medium term. This is due to the country's large size, low rural population density and the challenges facing the grid infrastructure. Estimates show that about half of the rural population may be more cost-effectively served by decentralized, off-grid solutions (Odarno et al., 2017). This increases the potential for the development of mini-grids in Tanzania as a promising contribution to Tanzania's future energy supply.

As illustrated in Figure 1 below, by April 2017, Tanzania had installed at least 110 mini-grids across 21 regions, with a total installed capacity of 155.2 MW and connections to at least 185,000 customers. Of the 110 mini-grids, sixteen were connected to the national grid, and 94 were operated as isolated mini-grids.

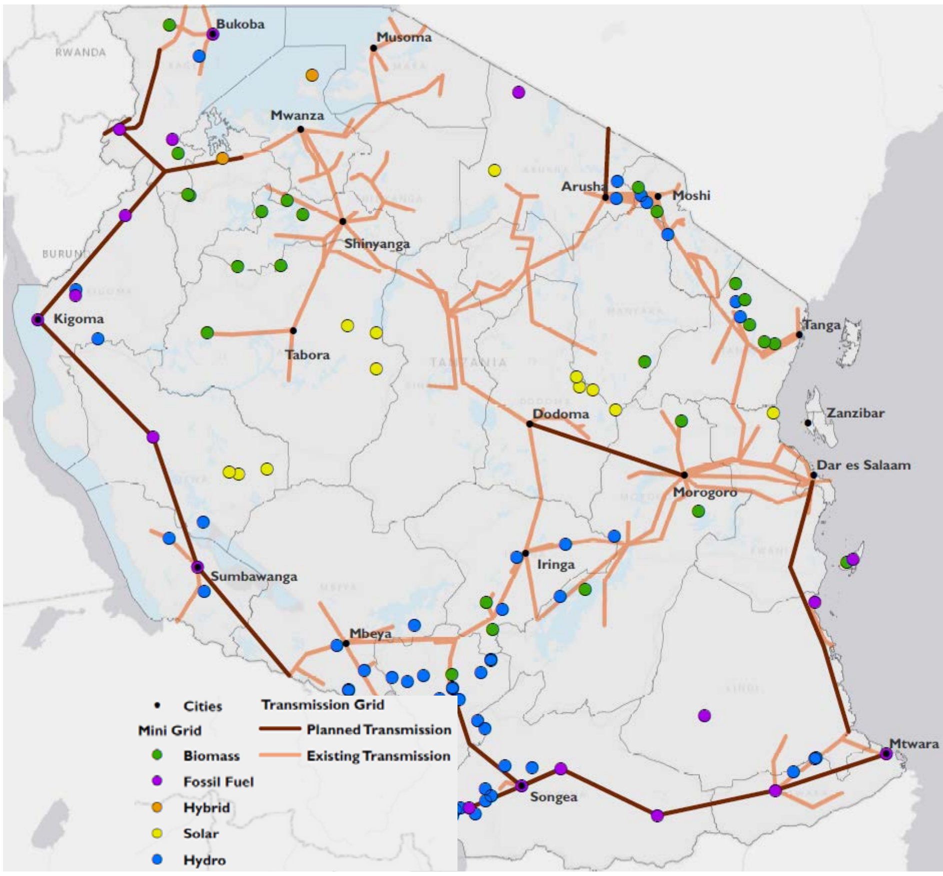

Figure 1. The locations of 110 mini-grids in Tanzania in 2017 by type of energy technology, along with planned and existing transmission grids. Source: https://energydata.info/dataset/mini-grid-locations-in-tanzania

Mini-grids were not required to register their operations before the establishment of the 2008 SPP framework (as described in the previous section). Because of this many small hydro mini-grids are not licensed or registered, and data are not available for them. Most of these plants produce less than 200 kW. Data on small diesel and biomass plants are also missing. Thus, the figures presented here must be interpreted with care, since comprehensive data are not available for each mini-grid. A full list of the existing mini-grids is provided in Annex 1, which also provides information on, for example, specific plants, coordinates, commission year and specific ownership.

Tables 1 and 2 give descriptive statistics of the list of mini-grids in Annex 1. Table 1 shows the distribution of ownership and energy source. The majority of the mini-grids are privately owned (37), while missions own 28, communities 19 and TANESCO 24. The TANESCO sites are mainly based on fossil fuels and to some extent hydro. Most of them are above 1 MW, and all of them above 150 kW. These mini-grids serve major towns, and 14 of the 24 have been in operation since before 2000 (see Table 2). The plants owned by missions are all hydro plants, nineteen of them below 150 kW (see Table 2). Biomass plants are almost entirely privately owned and include large MW plants and a number of small multifunctional platforms (MFP) fuelled by Jatropha oil and diesel. Solar plants are mainly owned by communities and most smaller hydropower plants by missions.

Ownership	fossil	biomass	hydro	solar	hybrid	Total
TANESCO	19		5			24
Government			3			3
Community		1	6	11		18
Mission			28			28
Private		24	8	2	3	37
Total	19	25	50	13	3	110

Table 1. Installed capacity in kW and number of connections to Tanzania's mini-grids by energy source, 2017. Data source: https://energydata.info/dataset/mini-grid-locations-in-tanzania

Table 2 gives the size of the sites according to ownership. It is worth noting that 50 of the 110 sites are above 150 kW and 49 of the remaining 60 are below 50 kW. The smaller mini-grids are mainly privately owned (12 of them MFPS), while the rest are owned and operated by communities and missions.

Size (kW)	TANESCO	Government	Community	Mission	Private	Total
<50		1	13	13	22	49
50-100			1	3	2	6
100-150			1	3	1	5
>150	24	2	3	9	12	50
Total	**24**	**3**	**18**	**28**	**37**	**110**

Table 2. Number of mini-grids by size and energy source, 2017. Data source: https://energydata.info/dataset/mini-grid-locations-in-tanzania

4. Plans for rural electrification

During the past several years, the rate of electrification in Tanzania has increased significantly. In 2014, the average national rate of electrification amounted to 36 percent, having increased from a level of only 7 percent in 2011 (The World Bank, 2016). However, the pace of rural electrification lags substantially behind the national average electrification rate from 2011. Scaling up access to modern forms of energy is a major priority for the government if it is to reduce extreme poverty and foster opportunities for productive economic activities. The updated National Energy Policy of 2015 stresses the lack of access to affordable and reliable electricity as a major constraint in achieving the desired socio-economic transformation in Tanzania. However, the potential of renewable energy solutions is largely under-exploited in the Power Systems Master Plan (PSMP 2016), the Tanzanian government's strategic plan to guide the development of the country's power system for the next 25 years (CEE 2018). Priority in the PSMP is the installation of large-scale thermal generation in order to serve as base load plant and to strengthen supply to the national grid, while distributed generation, including mini-grids, is not mentioned. However, the Government of Tanzania has embarked on an ambitious National Rural Electrification Program (NREP) to accelerate significantly the connection of rural households to the national grid. The NREP is currently being further refined in the Rural Energy Master Plan (REMP), which a consortium of consultants embarked upon in April 2017[3] (REA, 2017). Off-grid solutions, including mini-grids, have been included as part of the goal to achieve universal access. However, according to communication with IED, in the REMP the focus is currently on grid-connection. The mini-grid part has not yet been embarked upon due to delays in the project, which was planned to be finalized by September 2018.

4.1 National Rural Electrification Programme

The National Rural Electrification Program (NREP) for 2013–2022, which is guided by the National Electrification Program Prospectus (henceforward 'the Prospectus'), contains the government's main guidelines for electrification efforts, including in rural areas (Innovation Energie Developpement, 2014). The NREP focuses on both on-grid electrification, through four phases, and off-grid electrification.

4.1.1 Grid extension

REA oversees the rural electrification plan and the turnkey scheme, as well as any other rural energy issues in Tanzania. Medium-voltage extensions and low-voltage distribution grids are constructed under the turnkey scheme to connect the first wave of customers. At the end of the construction work, ownership of all assets is transferred to TANESCO.

As mentioned earlier, the least-cost electrification technology for areas that are not far from the grid and are relatively densely populated is connection through grid extension (Innovation Energie Developpement, 2014). With one exception, described below (Phase

[3] The consortium consist of Multiconsult, IED and TATEDO: https://www.ied-sa.fr/en/home/newsgb/243-rural-energy-master-plan-remp-launch-in-tanzania.html

3), the term “not far” has been defined as 10 km from the 33-kV grid. Population size has been used to determine the density, such that settlements with fewer than five hundred inhabitants at the time connection to the grid was considered were excluded from grid extension.

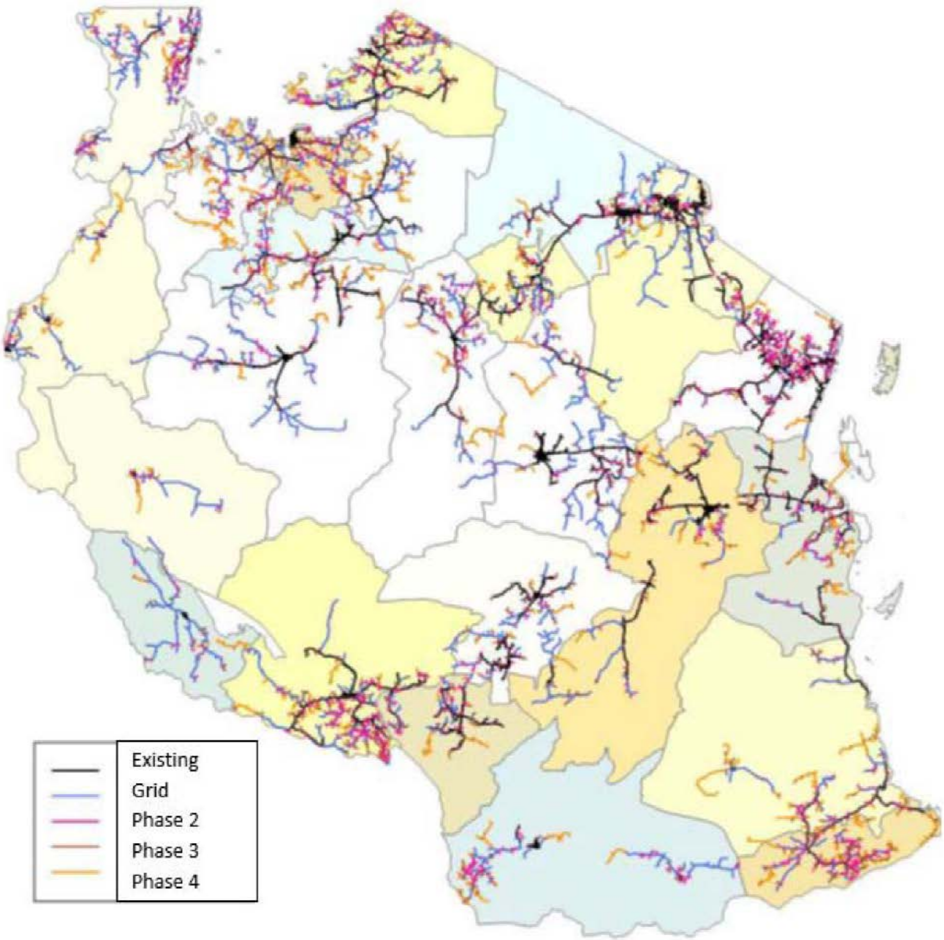

Figure 2. Map of Existing MV Lines and Phased Electricity Network Expansion under National Rural Electrification Program. Source: (Innovation Energie Developpement, 2014)

Electrification by grid extension is planned to be implemented in four phases, described below and indicated on the map in Figure 2.

- **Phase 1**, or Turnkey II, as referred to by REA, aimed to electrify almost 1,500 settlements by expanding the grid in the period 2013-2015.
- **Phase 2**, referred to by REA as Turnkey III, aims to electrify settlements within 10 km of the existing 33 kV medium-voltage network, which became available by the end of 2015, and to extend medium-voltage networks to enable the execution of Phases 3–4. The connection will be done, in the period 2016-2019, by a 33-kV line if the settlement has more than two thousand inhabitants. If it has between five hundred and two thousand inhabitants, connection is done by single-wire earth return (SWER). 1,740 settlements will be connected by three-phase lines and 1,256 by SWER technology from Turnkey III.

- **Phase 3**, or Turnkey IV as referred to by REA, aims to electrify 266 development centres within forty kilometres of the medium-voltage grid, which is likely to have been constructed by the end of 2019. The electrification of the development centres in Turnkey IV is assumed to occur in the years 2020–2022 (see section on off-grid electrification below).
- **Phase 4**, part of Turnkey IV as referred to by REA, aims to electrify 780 settlements that are within ten kilometres of the feeder lines constructed in the Phase 3 settlements by means of grid extension. The connection is done by a 33-kV line for 506 settlements, each of which has more than two thousand inhabitants at the time of electrification. Connection will be done by SWER for 274 settlements with between five hundred and two thousand inhabitants, and Phase-4 electrification would take place in the period 2020–2022.

According to the 2014 plan, by 2022 there will still be 3400 settlements (10.5 million inhabitants) out of a total of 12,248 settlements which will still lack electricity. If the grid is extended as planned and a new ten-kilometre buffer zone for grid connection is set aside for further grid connection after 2022, there will still be 1450 settlements not connected to the grid, described as 'deep rural areas'. Of those, 416 settlements will have a population of above two thousand (Innovation Energie Developpement, 2014).These figures, which are summarized in Table 3, show that there is a substantial market for private mini-grid operators to install mini-grids with a capacity below 100 kW, which is the current upper limit for installing mini-grids without a licence. If the grid connection progresses as planned, this market will be somewhere between 3400 and 416 settlements, and if delays occur, this figure will be even bigger.

The numbers and spatial situations of these settlements are expected to be more precisely described in the REMP, which is planned to be launched in September 2018.

	Total	Population In millions
Rural settlements	12,248	
Non-electrified settlements by 2022	3,400	10.5
Included in 10 km buffer zone from grid in 2022	1,950	5.5
Deep rural areas	1,450	5.1
Deep rural > 2000	416	1.4

Table 3. Overview of settlements not reached by the grid extension plan by 2022. (Innovation Energie Developpement, 2014).

4.1.2 Planned electrification with mini-grids

Specific electrification plans have been devised for a large number of so-called '*development centres'*, which are given a higher priority in the electrification plans. A development centre in this context is defined as a settlement with at least 1,500 inhabitants as of 2012, with some existing social or administrative infrastructure (school, dispensary, police station etc.), good access by road, and some business activities (Innovation Energie Developpement, 2014). A spatial analysis carried out for the Prospectus ranked the settlements that remained to be electrified based on their estimated socio-economic development potential. The potential also served as an indicator of the benefits of electrification.

The simulations for the Prospectus were carried out using the GIS database in order to arrive at an idea of the size of the potential market for off-grid electrification using renewable sources of energy for power production. The results identified 1,192 development centres out of 12,248 rural settlements. In Table 4 below, the regional distribution of the 1,192 development centres is shown. 693 of them have not yet been electrified.

	Total		Not Electrified	
Region	**Development Centres**	**Population in Development Centres in 2012**	**Development Centres**	**Population in Development Centres in 2012**
Arusha	46	249,378	15	47,956
Dar Es Salaam	82	869,431	13	93,311
Dodoma	53	571,126	40	171,537
Geita	37	205,704	34	198,472
Iringa	31	226,822	22	72,123
Kagera	63	310,900	47	161,457
Katavi	15	67,427	12	53,732
Kigoma	20	341,762	15	173,138
Kilimanjaro	57	340,182	13	39,836
Lindi	58	203,546	44	118,813
Manyara	39	205,034	20	98,106
Mara	44	267,359	24	76,316
Mbeya	59	481,285	39	119,431
Morogoro	133	894,458	77	334,751
Mtwara	38	199,042	32	76,151
Mwanza	88	341,292	45	161,035
Njombe	16	61,383	8	22,252
Pwani	85	338,150	50	135,676
Rukwa	16	188,067	15	61,272
Ruvuma	19	195,209	16	53,557
Shinyanga	26	242,569	13	46,213
Simiyu	28	127,138	24	108,445
Singida	42	252,482	32	98,307
Tabora	35	368,439	22	89,382
Tanga	62	256,685	21	79,401
TOTAL	**1192**	**7 804 870**	**693**	**2 690 670**

Table 4. Regional Distribution of Development Centres Source: (Innovation Energie Developpement, 2014)

The spatial distribution of the 1,192 development centres can be found in Figure 3 below. The map also shows electrified and non-electrified rural settlements.

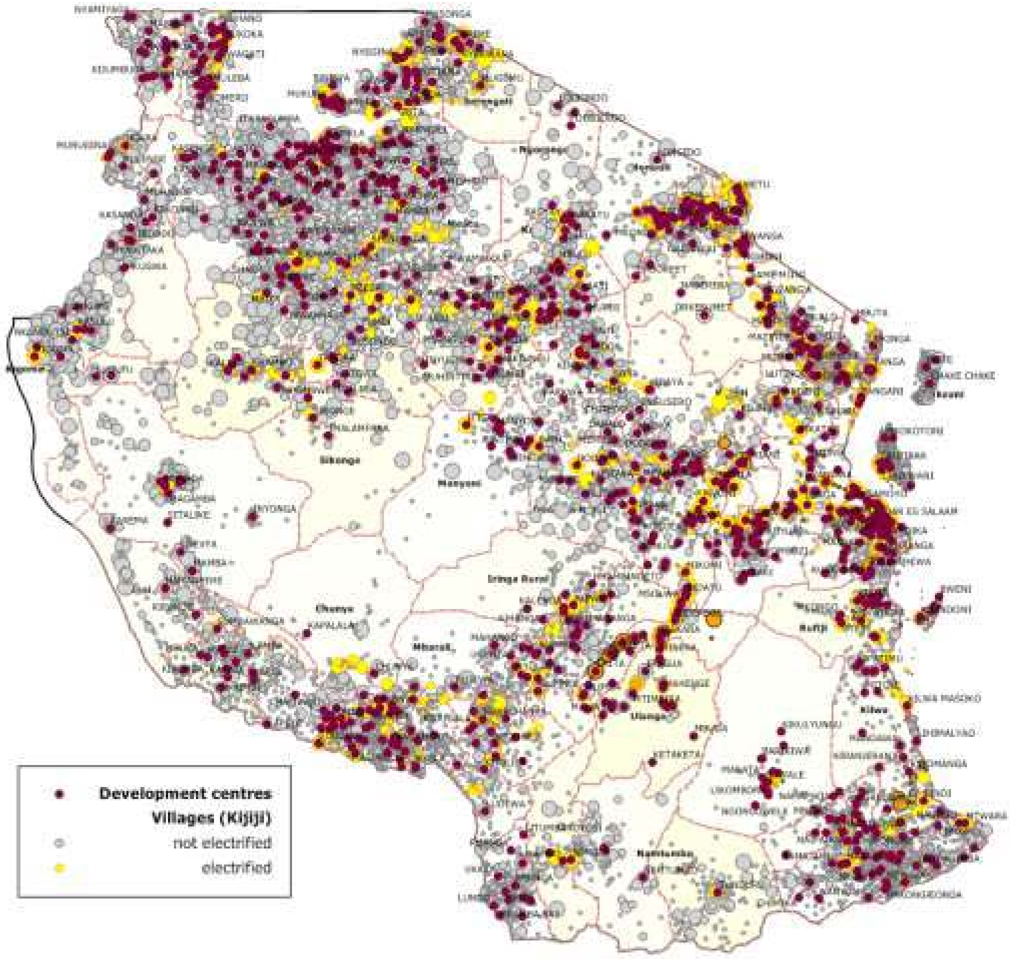

Figure 3: Map the identified development centres, and electrified and non-electrified settlements. Source: (Innovation Energie Developpement, 2014)

Most of the 693 identified centres that have not yet been electrified were planned to be reached by the grid expansion programmes (see phase 3 in the previous section), but according to the plans, 226 of them would not be connected to the main grid until 2020. If there are delays to the grid extension, as is likely, a substantial proportion of these centres might be available for mini-grid development. (Innovation Energie Developpement, 2014).

According to the plan, 154 of the 266 development centres with more than 2500 inhabitants were considered for mini-grids, as shown in Table 5.

Off-grid Technology	Number of Settlements	Inhabitants	Number of Customers in 2022
Small Hydro-Plants	18 (13 plants)	over 2500	40,436
Rice husk-fuelled Gasifiers	63	over 2500	9,256
Diesel-PV Hybrids	73	over 5000	57,943
Total	**154**		**107,635**

Table 5. Mini-grid projects and their technology type for development centres not connected to the grid until 2020. Source: (The World Bank, 2016) (Innovation Energie Developpement, 2014).

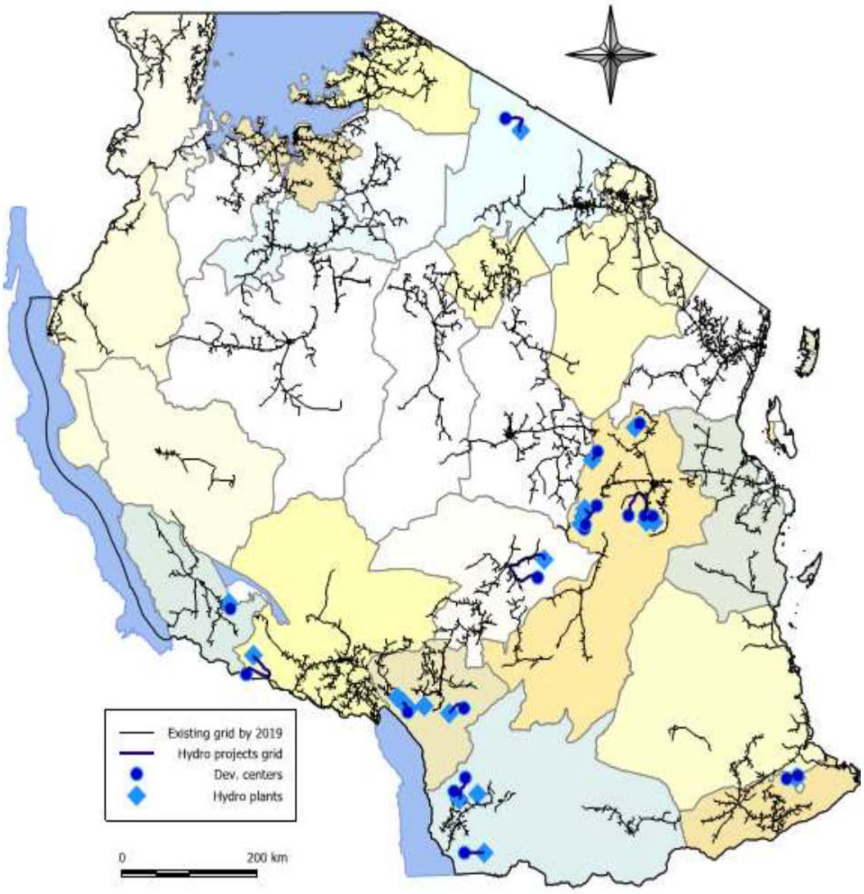

Figure 4. Planned hydro-plants and development centres. Source: (Innovation Energie Developpement, 2014)

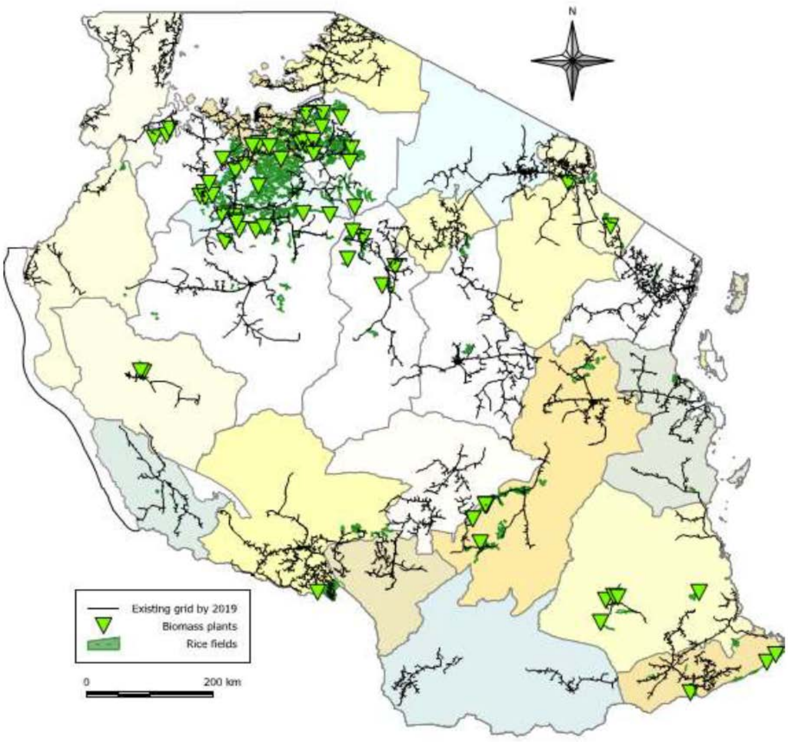

Figure 5. Planned biomass plants for development centres. Source: (Innovation Energie Developpement, 2014)

Geographic coordinates were not available for the 154 sites, so the project has not been able to provide an assessment of the wind potential of these sites (see section 3.1.1). As a next best solution the maps in the prospectus have been reproduced here as Figures 4, 5 and 6 (Innovation Energie Developpement, 2014).

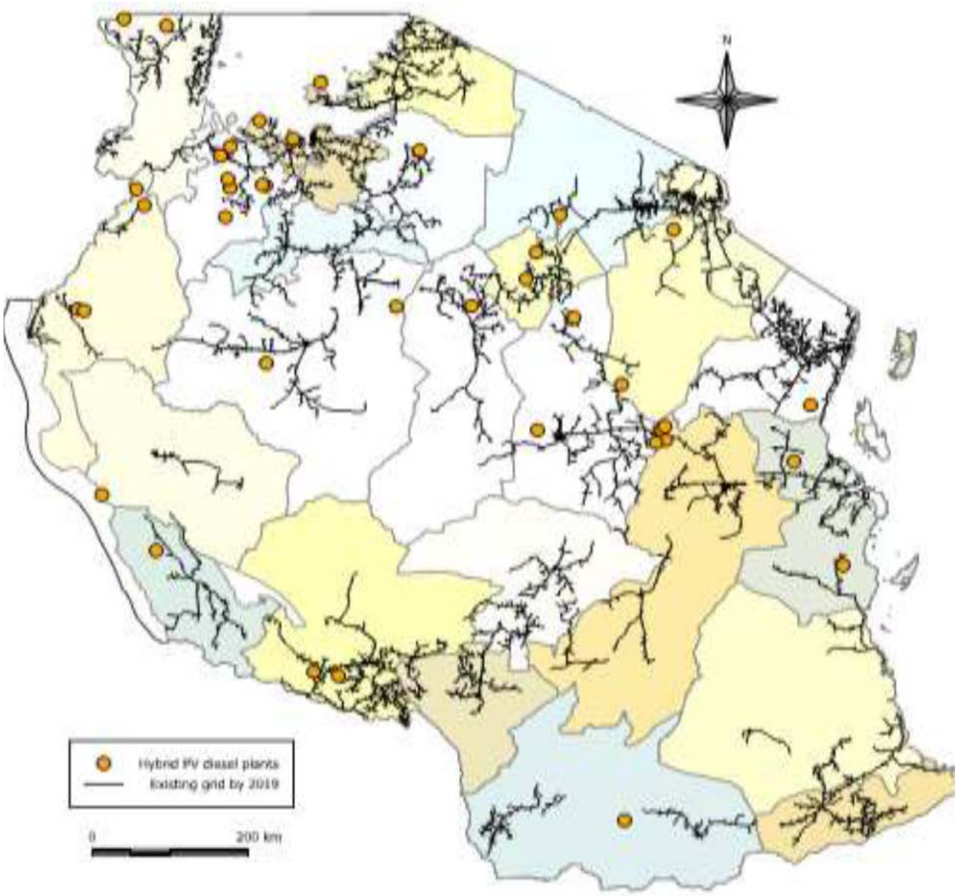

Figure 6. The location of diesel-PV systems for prioritized development centres. Source: (Innovation Energie Developpement, 2014)

4.1.3 Summary of current and developing mini-grids and grid extensions

In order to accelerate the electrification rate in rural areas significantly, the least-cost electrification technology for settlements close to the national grid is connection by grid extension. For that reason, in 2013 the Government of Tanzania embarked on an ambitious program, the National Rural Electrification Program (NREP), to run from 2013 to 2022. This programme aims to electrify about 5,500 settlements by the end of 2022 through four phases of grid-extensions.

Currently, at least 110 mini-grids have already been identified across 21 regions in Tanzania, with a total installed capacity of 155.2 MW. Of the 110 mini-grids, sixteen were connected to the national grid and 94 operated as isolated mini-grids. The TANESCO sites are mainly based on fossil fuels and to some extent hydro. Most of them are above 1 MW, and all of them above 150 kW. The sites owned by missions all depend on small-scale hydropower. The majority of sites owned by TANESCO and the missions were established before 2000, while the vast majority of community- and privately owned grids have been established since 2010. These recent sites are mainly based on solar power biomass in te form of Jatropha oil and small-scale hydropower.

According to plans, more than 3,400 settlements will not be reached by the grid by 2022 and are therefore left as potential candidates for mini-grid electrification. While specific plans are underway, these sites (< 100 kW) can be electrified without mini-grid developers needing a licence.

Specific plans for electrification by mini-grids have been devised for a large number of so-called '*development* centres'. In the Prospectus, 1,192 development centres were identified as being a potential market for off-grid electrification using renewable energy sources for power production. 693 of them had not yet been electrified. While it is planned to reach many of these by means of the grid expansion programmes, specific plans for mini-grids have been drawn up for 154 centres that were not expected to obtain a grid connection until 2020. This date is likely to be postponed.

5. Public and private market players

Mini-grid systems can be owned and operated by a range of different actors: rural electrification agencies, state-owned utilities, private independent power producers, faith-based organizations and municipalities (Johnson, 2016). Today, the national utility (TANESCO), private businesses, faith-based organizations and local communities own and operate over a hundred mini-grid systems in Tanzania. In addition, donor-funded mini-grids implemented by NGOs are also operating in Tanzania, as seen in Figure 7 below, where the NGOs ACRA and CEFA supply hydropower. Once operational, they are left to be managed and operated by local rural communities.

5.1 Private market players: current and planned activities

Many private market players are active in providing rural Tanzania with electricity from hybrid RE sources. During this study, more than 25 private companies were identified, though many of them are working with either larger scale energy production (in MWs) or in the smaller pico-/micro-scale market by providing solar home system (SHS) solutions. Approximately ten of the 25 private market players identified were mainly providing SHS solutions, and another handful were making larger MW-scaled power projects. In the end, seven private companies were identified that are currently planning and/or own mini-grid projects in Tanzania. Two of these were Kenyan Powerhive and PowerGen, which are described in the separate market study for Kenya and will not be presented here.

Table 6 below gives a list of the private companies identified:

Private company	No. of active mini-grids	Average size of mini-grids	Customers	Contribution to SDGs
REDAVIA	6	280 kWp	Agriculture, mining & minerals	7, 13
ENSOL Ltd.	1 pilot project	50 kWp	Community, SMEs	7, 13
JUMEME	1 pilot project	(60) 380 kWp	Telecom industry, mines and SMEs	7, 13, 5
Rafiki Power	8	10.5 kWp	Community, SMEs	7, 13
PowerCorner	1 pilot project	16 kWp	Community, SMEs	7, 13

Table 6. Private companies identified and their characteristics

The criteria for choosing the mini-grid market players within the scope of the project are:

Having a renewable energy source in the mini-grid system:

- Owning/operating the mini-grid
- Have ongoing or planned mini-grid projects in Tanzania below 100 kWp, preferably in the range of 10-50 kWp.
- Having valid business and project information available

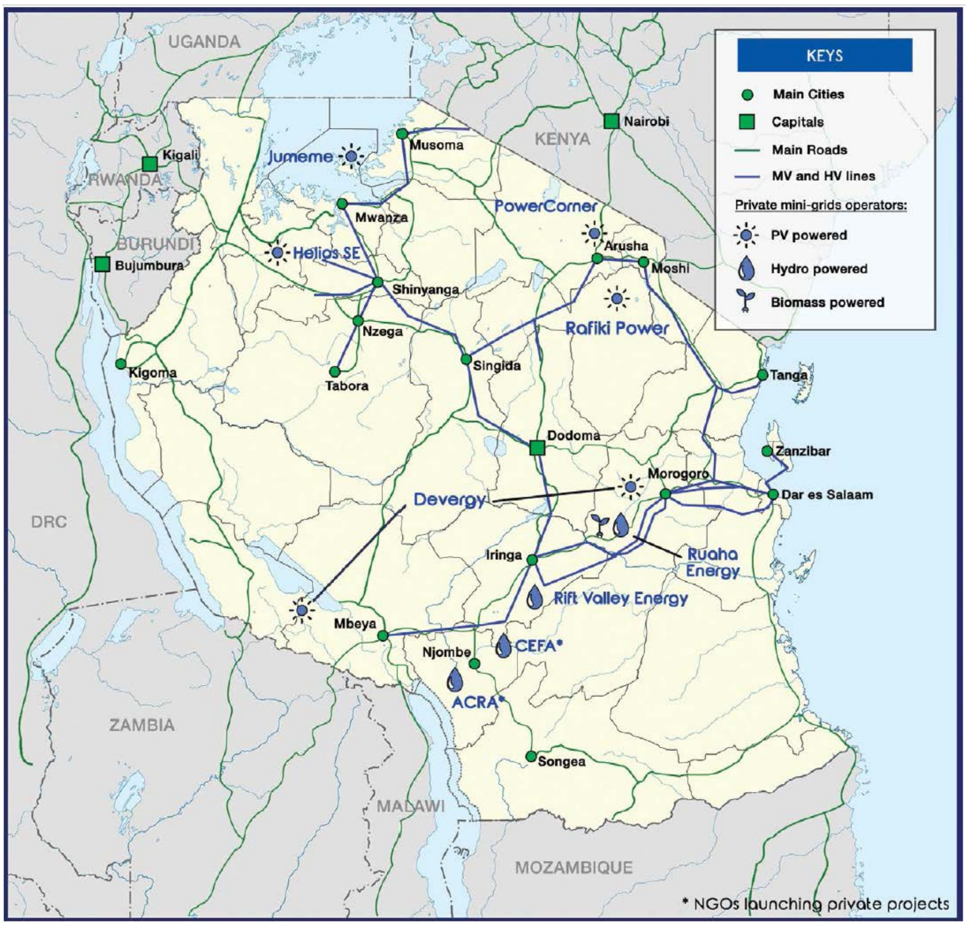

Figure 7. Main private mini-grids operators in Tanzania. Source: (Contejean & Verin, 2017)

The most prominent private market players to be identified were REDAVIA, ENSOL Tanzania Ltd., JUMEME, Rafiki Power and PowerCorner. Their current and planned projects will be described in the following section.

Figure 7 provides a geographical representation of where some of the private market players operate. Displayed among others here are the three companies JUMEME, PowerCorner and Rafiki Power, according to a study made by (Contejean & Verin, 2017). The other private market players, Devergy, Ruaha Energy and Helios SE, mainly supply SHS or larger-scale mini-grid or utility projects.

5.1.1 REDAVIA

REDAVIA, with its headquarters located in Munich, Germany, was founded in 2010 and has provided rental mini-grids to businesses and communities in Ghana, Tanzania and Kenya since 2013. Currently the company has six solar projects in operation in East Africa, four of them in Tanzania.[4] The REDAVIA mini-grid solution includes a solar container with a 89 kWp capacity, supplemented by integrated lithium-ion energy-storage devices (90 kVA / 165 kWh and 60 kVA /138 kWh). Each of its different projects has the

[4] http://www.energyafrica.de/fileadmin/user_upload/Energy_Africa_16/EA16_Redavia.pdf

number of containers necessary to supply the demand for energy. The solution is seamlessly integrated into existing power infrastructure, thus supplementing diesel generators and/or grid-connected power, and using batteries when economically feasible.[5]

REDAVIA's most recent projects date from October 2017, when two mini-grids were commissioned in Isenzanya and Shitunguru, located in the Songwe region of western Tanzania.[6] These mini-grid solutions include two solar containers with a total capacity of 178 kWp.

In July 2017 an initial one-container solar plant from 2014 at Shanta Gold's New Luika mine in Chunya District was scaled up to an eight-container solar farm with a total capacity of 674 kWp.[7] REDAVIA's last two projects in Tanzania are another mining farm, the gold mine in Mbeya, and an 87 kWp solar system for the sawmill in Sao Hill. Information regarding the two latter projects has been limited.

REDAVIA's customers are mainly communities, as well as agricultural and food-production companies. Providing support to utilities and industrial consumers is also part of REDAVIA's business, although to a lesser extent.[8]

According to its mission statement, REDAVIA wants to be the global market leader in producing cost-effective, reliable rental solar-power solutions for businesses and communities in order to reduce emissions, but it has not announced any planned activities for the future. The company says that it will soon roll out enhanced solar technology with more intuitive features and begin scaling up its mini-grid operations.[9]

5.1.2 ENSOL Tanzania Ltd

ENSOL Ltd is a Tanzanian company established in 2001 with the purpose of supplying, installing and maintaining SHS and small hydro and photovoltaic micro- and mini-grids in Tanzania. ENSOL develops, installs and operates solar PV, back-up and water-heating equipment and systems. Unfortunately, it has not been possible to determine the total number of its projects besides that in Mpale village.

In 2012-13, ENSOL supplied and installed a solar-operated water-pump system in Mtwara in the south of Tanzania.[10] All eleven villages in Mtwara Rural were supplied with a solar water-pumping system (size unknown) capable of supplying a maximum of 50,000 litres of tap water a day. A water committee in each village is responsible for collecting small contributions from residents to sustain the project. The USD 340,000 project was financed by the European Union and administered by the African Medical and Research Foundation (AMREF). Procurement was conducted through open competitive tendering.

[5] https://www.redaviasolar.com/wp-content/uploads/redavia_rental-solar-power_company-overview.pdf
[6] https://www.redaviasolar.com/redavia-commissioned-largest-minigrid-tanzania/
[7] https://www.redaviasolar.com/redavia-commissioned-tanzanias-largest-solar-farm-shanta-gold/
[8] http://www.energyafrica.de/fileadmin/user_upload/Energy_Africa_16/EA16_Redavia.pdf
[9] http://eepafrica.org/wp-content/uploads/IBM_Redavia_Final-Version.pdf
[10] https://www.ruralelec.org/project-case-studies/ensol-limited-supply-and-installation-solar-operated-water-pumps-mtwara

In September 2017, a 50-kW project launched by the United Nations Capital Development Fund and Ensol Tanzania Ltd. has connected at least fifty households in Mpale village, Korogwe District, to a solar mini-grid.[11] Plans are underway to expand the project by connecting a total of 250 households by June 2018. Mpale Village has 730 households and 3000 residents, who previously used kerosene for lighting.

Ensol Ltd. is planning to establish fifteen more projects like the mini-grid in Mpale Village within the next five years, using this one as a learning opportunity. The company is scouting the southern highlands to find other villages suitable for developing similar solar-power projects, and it is working on agreements with local governments to bring them solar power.[12]

5.1.3 JUMEME

JUMEME, a private micro-utility, was founded in 2014 with the aim of developing and implementing a large portfolio of solar-hybrid mini-grids in rural growth centres in Tanzania. The off- and on-grid mini-grid operator uses solar-battery-diesel hybrid power systems connected to medium- and low-voltage distribution networks.

The development of the pilot solar-hybrid mini-grid system in the village of Bwisya on the Lake Victoria island of Ukara started already in August 2015, and the system has been operating since April 2016. The initial mini-grid system was configured using a 60 kWp solar power unit, a 30 kVA diesel genset and a storage system consisting of 240 kWh batteries. In addition, it had a seven-kilometre distribution grid with 250 connections. During 2017, the mini-grid system was extended to the other seven villages on the island, resulting in an installed solar power capacity of 380 kWp and 81 km of low and medium voltage distribution grid.[13]

The pilot project, jointly funded by the European Union and private investors with political support from the Tanzanian government, had a total budget of 38.4 billion shillings (USD 17.3 million).[14] The installation charges for individual homes and business are repaid by customers in instalments. Consumers pre-pay for their power, with costs per unit depending on the amount of electrical equipment they use. At the end of 2014, the Sustainable Energy Fund for Africa approved a USD 420,000 preparation grant to JUMEME – Rural Power Supply Ltd to support the development of a portfolio of independent solar-hybrid mini-grids in rural growth centres in Tanzania.

JUMEME has an extensive pipeline of projects, the initial phase, scheduled to run until 2017, including approximately 28 mini-grids. The company's focus is on supplying to sectors such as the telecoms industry, mines and small businesses, and it aims to provide energy services to more than 100,000 people and 2,340 shops and small businesses by 2018. In the longer term, its goal is to set up three hundred systems and serve up to one

[11] http://www.decentralized-energy.com/articles/2017/09/tanzania-solar-microgrid-comes-online.html
https://dailynews.co.tz/index.php/business/53059-village-solar-microgrid-project-launched-in-korogwe
[12] http://www.decentralized-energy.com/articles/2017/09/tanzania-solar-microgrid-comes-online.html
[13] http://www.energynet.co.uk/webfm_send/1946
[14] https://www.reuters.com/article/us-tanzania-solar-energy/solar-panels-power-business-surge-not-just-lights-in-tanzania-idUSKCN0XG1VX

million people in rural areas across Tanzania by 2022. According to the (European Union, 2015), JUMEME will also become a fully functioning, sustainable and profitable electricity company by 2018, and it currently operates as a profitable private mini-grid utility.

5.1.4 Rafiki Power

Rafiki Power, which was founded in 2013 and is owned by German E.ON, has installed and operate eight mini-grid solutions (solar PV and battery) electrifying more than seven hundred households in rural Tanzania by implementing standardised solar AC grids with a minimum capacity of 6 kW. Rafiki Power is the Tanzania brand of German E.ON Off Grid Solutions, which provides rural households with electricity by selling off-grid systems. The first project was launched in 2014, and Rafiki Power is expected to spend USD ten million on off-grid solutions to over eight hundred households in the Arusha, Manyara and Dodoma regions.[15]

Of other projects, a 6kWp PV/battery hybrid system was installed in Ololosokwan at the end of 2015. Unfortunately there is no more information regarding this project. Further, in April 2017, a 15 kWp PV/battery hybrid system water-pumping system was installed in Chang'ombe and Dongo villages in Manyara Region's Kiteto District, connecting 144 households to electricity.[16]

The company has plans to electrify over a hundred villages by 2020.

5.1.5 PowerCorner

PowerCorner is an internal start-up by the French multinational utility company ENGIE to provide electricity access in rural Africa with the help of off-grid distributed energy solutions, especially sustainable energy-based mini-grids.

Launched in 2015 and finished in 2016, Ketumbeine, a village that is home to eight hundred people, was the first electrification project carried out by PowerCorner.[17] Located in northern Tanzania, in Longido District, its 16 kWp, 45 kWh of lithium batteries and a back-up genset, containerized production unit can provide power to 120 houses and businesses and is currently providing electricity to fifty clients, including households and SMEs. At the heart of PowerCorner's mission, the next step is to connect most of the productive machines by replacing old fuel-powered machines (milling, grinding, welding, water pumping) with efficient electric ones.

PowerCorner's pilot project in Ketumbeine was financed entirely by ENGIE.[18] The overall costs for the pilot were EUR 140,000. The pricing model for the end-users reflects their ability to pay and the expenses incurred from the mini-grid over time (CAPEX and OPEX) aligned with current needs and the future demand from the population. This particular

[15] http://www.thecitizen.co.tz/News/Business/German-firm-keen-to-light-up-rural-areas/1840414-3921066-format-xhtml-xjg9d/index.html

[16] http://www.dailynews.co.tz/index.php/home-news/2-uncategorised/50379-electricity-uplifts-people-s-spirits

[17] http://powercorner.com/

[18] https://www.ruralelec.org/project-case-studies/powercornerengie-ketumbeine-mini-grid-16-kw-pv-panels-45-kwh-lithium-batteries

project will not pay off in terms of economic return itself, but it will be tested for a roll-out of several mini-grids in Tanzania for ENGIE that will prove their business model's economic feasibility.

The goal is to adapt and replicate the model in other towns in Tanzania, as well as developing new pilots in other countries in Africa.

5.2 Business models used and their impact on SDG's

The way in which mini-grids are designed, financed and operated – their so-called business models – can vary widely, particularly with regard to financing and operation (Johnson, 2016). For example, investment may come in the form of donor grants or government funding and might be divided into four categories; *utility operator, private operator, community operator* or *hybrid operator*. For Tanzania, as also described in Chapter 2, most identified mini-grid expansion plans are carried out and managed by a utility operator, namely a government managing all aspects of the mini-grid. However, the business models from the private market that are described in this chapter seems to be private operators, private companies managing all aspects in both regulated and non-regulated environments.

The five private market players identified in the Tanzanian mini-grid market do not have any clear business model description. However, they all greatly emphasize the goal of becoming leaders in providing easy access to affordable and clean energy in rural Tanzania. All the market players are committed to using renewable energy sources, mainly solar power, as a key driver to having a sustainable, social and economic impact locally.

JUMEME, however, does have a brief description of it project financing and business model. The profitable private mini-grid utility will provide approximately 50% of the project costs through private finance (both equity and debt). JUMEME has adopted the award-winning "Micro Power Economy" business model developed by INENSUS, which incorporates a combination of community-oriented governance, modular capacity planning and smart meters for demand and load management with a tariff block structure (European Union, 2015).

REDAVIA's mission is to provide cost-effective, reliable and clean solar energy to enable businesses and communities to grow sustainably.[19] Like most other private market players, it wants to be the global market leader in the provision of cost-effective, reliable rental solar power solutions for businesses and communities so as to reduce their emissions. REDAVIA works with a so-called "rental model" consisting of re-deployable solar farms that enables shorter off-taker contracts and requires no upfront investment.[20] The rental model increases the flexibility to scale up solar energy capacity by simply adding new containers of solar panels when the demand for electricity increases. This solution enables faster uptake of the system.

[19] http://eepafrica.org/wp-content/uploads/IBM_Redavia_Final-Version.pdf
[20] http://eepafrica.org/redavia-innovative-business-model-rent-the-solar-own-the-future/

JUMEME's pilot project showcases the positive social, economic and environmental impacts of a sustainable electricity supply, based on a business model that provides so-called "development opportunities" for rural citizens and fair returns for private investors.[21] These development opportunities are not elaborated further. JUMEME is working with GVEP International, an NGO, to train people in Ukara to use electricity for business purposes, such as producing wood and metal crafts.[22] In addition, the expected impacts and results from JUMEMEs many planned mini-grid projects include the creation of five hundred new businesses (agricultural and productive users), as well as increased access to food and water, and improvements to the environment and gender equality (European Union, 2015).

By interpreting the few lines of descriptive visions, missions and goals from the five identified market players, it appears that they are making very similar contributions to the SDGs. Very obviously they all contribute to SDG 7 – Affordable and Clean Energy; 13 – Climate Action; 11 – Sustainable Cities and Communities, 3 – Good Health and Well-Being; and to some extent 8 – Decent Work and Economic Growth. For example, Ensol's Mpale village mini-grid project has now connected the local health centre, while the provision of electricity has generated more local economic development.[23]

REDAVIA and JUMEME, which have industry among their main target off-takers, may contribute more to SDG 9 – Industry, Innovation and Infrastructure. Rafiki Power's main aim, nevertheless, is also to ensure that rural residents have access to reliable electricity to bolster local businesses and productive industry. Rafiki Power also has a solar water-pumping system operating in Chang'ombe and Dongo villages, which contributes additionally to SDG 6 – Clean Water and Sanitation, and agricultural land use.

Local economic and industrial development, along with electrical household lighting, could improve SDG 4 – Quality Education, and in the longer term SDG 1 – No Poverty.

5.3 Major donor-funding activities

Investments in off-grid solutions are often seen by private investors, policy-makers and users as temporary pre-electrification solutions favouring larger-scaled projects. In Tanzania, it is easier, or more convenient, for policy makers to finance a 100 million USD grid expansion project than it is to fund 100 x 1 million USD mini-grid projects[24]. According to Sebastian Rieger, Finance Director for Rafiki Power, politicians like to put their name on bigger projects, such as the conventional energy system, and donors, including the World Bank, also find it easier to invest in central-grid extension.

REDAVIA, however, has five private investors: (1) the Energy and Environment Partnership (EEP), a programme jointly funded by the Ministry of Foreign Affairs of Finland (lead donor) to promote renewable energy, energy efficiency and clean technology investments

[21] https://www.afdb.org/en/news-and-events/prize-winning-sefa-financed-jumeme-rural-electrification-project-in-tanzania-begins-operations-15578/
[22] https://www.reuters.com/article/us-tanzania-solar-energy/solar-panels-power-business-surge-not-just-lights-in-tanzania-idUSKCN0XG1VX
[23] https://dailynews.co.tz/index.php/business/53059-village-solar-microgrid-project-launched-in-korogwe
[24] http://www.powerforall.org/blog/2017/3/2/insider-insight-rafiki-power

in developing countries;[25] (2) InfraCo Africa, a company established by the Private Infrastructure Development Group (PIDG) to mobilize private-sector expertise and finance to develop infrastructure projects in sub-Saharan Africa;[26] (3) (PIDG), an organization funded by governments and multi-lateral agencies to mobilize private-sector investment in infrastructure within developing countries to boost economic growth and combat poverty; (4) REEEP, an international multilateral partnership, primarily funded by sovereign governments, multilateral and international organizations, that works to accelerate the market-based deployment of renewable energy and energy-efficient systems in developing countries[27]; and (5) the Shell Foundation, an independent UK-registered charity that creates and scales new solutions to global development challenges. In 2013, the Shell Foundation partnered with Redavia GMbH to help it expand and market its on-site solar farms. A year later, Redavia Tanzania Asset Ltd (or just REDAVIA) was founded by its parent organization with additional funding from REEEP.[28] InfraCo Africa will release up to USD five million in capital to finance thirty containers enabling REDAVIA to prove its business model and grow to a commercially viable scale.

JUMEME's lead partner is INSENSUS GmbH, which is helping it to develop its business model, and there are three additional international partners. The main project supporters are the European Union (with approximately USD 9.1 million) and EEP. To implement the pilot project in Bwisya in 2015, JUMEME received additional co-financing from the Energy and Environment Partnership Programme with Southern and East Africa. Grants for technical assistance were provided by the Overseas Private Investment Corporation (a self-sustaining U.S. government agency that helps American businesses invest in emerging markets[29]); the Sustainable Energy Fund for Africa (a multi-donor trust fund administered by the African Development Bank, anchored in a commitment of USD 60 million by the government of Denmark and the United States to support small- and medium-scale renewable energy and energy-efficiency projects in Africa[30]); and the Global Climate Partnership Fund (a public-private partnership that uses public funding to leverage private capital in order to mitigate climate change and drive sustainable growth in developing and emerging markets[31]).[32]

Besides the information already given above about these different companies, Rafiki Power, PowerCorner and Ensol Ltd. do not have additional available information regarding funding and donors.

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[25] http://eepafrica.org/about-us/
[26] http://www.infracoafrica.com/who-we-are/
[27] https://www.reeep.org/donors
[28] http://www.infracoafrica.com/project/redavia-2/
[29] https://www.opic.gov/
[30] https://www.afdb.org/en/topics-and-sectors/initiatives-partnerships/sustainable-energy-fund-for-africa/
[31] https://www.gcpf.lu/renewable-energy-and-energy-efficiency-investments.html
[32] https://europa.eu/capacity4dev/public-energy/blog/inauguration-solar-powered-mini-grid-ukara-island

6. Existing wind-turbine importers, manufacturers and installers

6.1 Historical account of small-scale wind in Tanzania

Wind power has not been used to generate electricity very widely in Tanzania, nor in other east African countries (Herick Othieno; Joseph Awange, 2015), and available information has been limited. However, off-grid wind energy has been used for water pumping in Tanzania for decades (GIZ, 2009). In 2009, at least 150 wind-pumping systems were installed by missionary projects, communities and private individuals, though not all are still operational. As many as several hundred small wind-turbine units have been installed in off-grid parts of the country. The highlands, coastal regions and Lake Victoria have average wind speeds suitable for both power generation and water pumping. However, in Tanzania a significant number of locally produced wind turbines have mainly been used for pumping water.

Since 1980 the Tanzanian government has supported the installation of wind pumps to supply water to several villages by, for example, organizing several workshops to encourage the production of prototype wind pumps. This makes the Tanzanian efforts to promote wind energy some of the best in the East African region (Herick Othieno; Joseph Awange, 2015).

6.2 Current status of firms in the sector

The most recent available information that has been found regarding the Tanzanian wind-power industry dates from 2009, indicating that there is no wind-power industry association in Tanzania. Though the responsibilities for current wind measurements, project developments, negotiations and installation reside within a few agencies, including TANESCO, the Tanzania Meteorological Agency, the Ministry of Energy and Minerals and Wind East Africa, a special-purpose company has been formed by a consortium of three stakeholders to develop, own and operate a large Singida wind-power station in Tanzania.[33] Beyond the assessment of wind resources for wind-energy projects, the development of local skills in project design and implementation has not yet reached the operational stage. Since retailers often lack the capacity to design and market off-grid wind systems, the support to develop these skills often comes from supplier companies or projects. Companies that install and design systems usually train their own staff or send them abroad for this training (GIZ, 2009).

Neither the off-grid wind-pump market nor the wind-generator market seems to have developed sufficiently to warrant an organized supply chain for products outside of occasional purchases. Suppliers of off-grid wind systems are still trying to establish themselves in the market (with several examples of start-up companies dissolving within a few years). Generally, wind generators are available on demand from the major solar suppliers (GIZ, 2009).

[33] http://www.energynet.co.uk/partner/wind-east-africa

The only two Tanzanian private-market players involved with wind energy identified today are Technosys Ltd. and DOBEA Energy Ltd.

Technosys Ltd. is reportedly a sister company of Technohub, a Ukrainian registered company. There seems to be no information about any such Ukrainian registered company, but in Romania a company called Technohub exists consisting of a team of professionals specialized in enterprise mobility and eBusiness solutions design.[34] Technosys Ltd. started operating in 2012 and consists of Tanzanian specialists dealing with the design, supply and installation mainly of solar equipment and some horizontal and vertical wind turbines.[35] It is unclear whether the company is involved in any activities or even whether it still exists due to a lack of information.

DOBEA Energy Ltd., a local company established in 2010, is dedicated to developing affordable and sustainable power projects targeting customers mainly in rural areas to enable them to achieve both electrification and access to clean water for domestic purposes and irrigation. In January 2018, the company graduated from the Tanzania Renewable Energy Business Incubator (TAREBI).[36] The company is a manufacturer of wind-turbine water pumps and electricity generators and solar-water pumps, using locally available materials. It also installs its own products, which also include solar kits, wind kits and hybrids. Reportedly, the company recently devised a solar-wind hybrid micro-grid system targeting rural off-grid households, business premises and institutions. This system involves the installation of at least 15 kW of hybrid solar–wind power plants, power storage and distribution to a number of households, business premises and institutions.[37] However, it has not been possible to find a webpage or any articles regarding this company.

[34] http://www.technohub.ro/about-us
[35] http://aquienergo.com/images/Blue_Cacbon/TechnosysCompanyprofile2015.pdf
[36] http://allafrica.com/stories/201801310319.html
[37] https://www.zoomtanzania.com/biz/dobea-energy

7. Assessment of wind potential at mini-grid sites

The aim of this chapter is to provide an assessment of the proportion of mini-grid sites in Tanzania that may be suitable for the integration of small wind turbines, based on estimates of the wind resources in the areas immediately surrounding a mini-grid. It should be emphasised that these estimates are not based on wind measurements at each site and are thus associated with a degree of uncertainty. However, the analysis is based on the very latest scientific wind resource data from the Global Wind Atlas. As such, it represents a very appropriate study when looking at a number of geographically dispersed sites throughout the country.

7.1 Methods for assessing wind resources

The basis for estimating wind potential is two sets of data: a) wind resource information from the Global Wind Atlas; and b) mini-grid site locations and mini-grid electrical capacities.

7.1.1 Extracting wind resource information from the Global Wind Atlas

The Global Wind Atlas uses large-scale wind-climate data and mesoscale modelling to obtain a set of generalized wind-climate data that cover the globe at a grid spacing of 9 km. These data are then subjected to microscale modelling techniques, which, together with topographical and land roughness data, produce a series of local wind climates for every 1 km of the globe at heights of 50, 100 and 200 m. More detailed information on this can be found on the Global Wind Atlas website (https://globalwindatlas.info/).

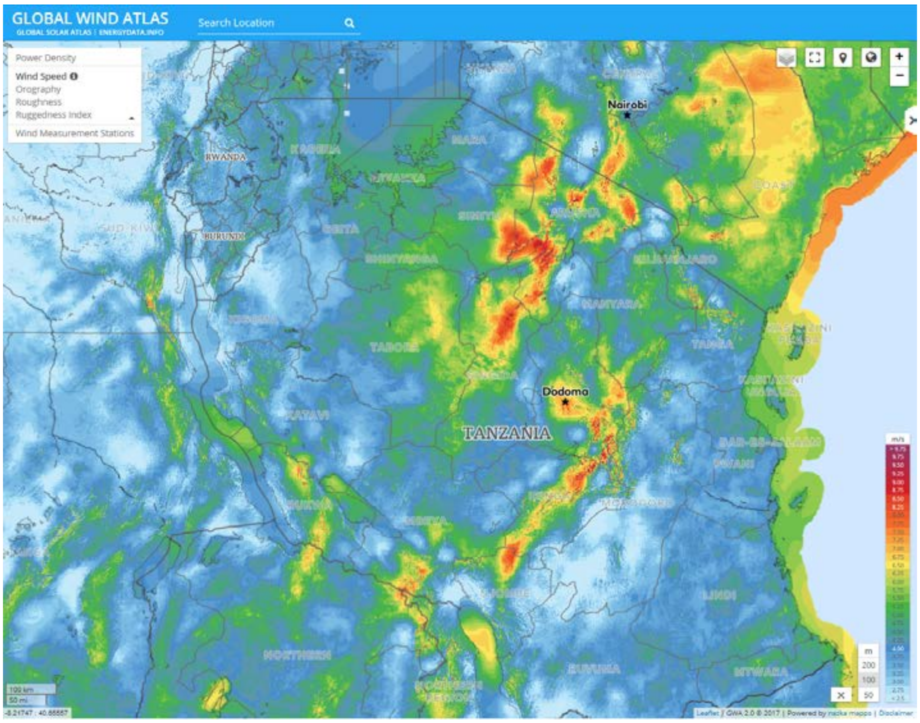

Figure 8. Screen shot from the Global Wind Atlas web-browser interface

The Kenya Miniwind project has put together an analytical tool that can help analyse the wind-climate data so that it can be related to specific mini-grid sites. The analysis is carried out within a radius of 2.5 km around each mini-grid site location. The reason for taking an area, rather than an exact location, is three-fold: 1) the production from a small wind turbine is very sensitive to location and should be located in the optimum position within a reasonable distance of the mini-grid, and not necessarily at the exact mini-grid location; 2) it is unlikely that the position of the local wind-climate data and the mini-grid location will coincide; and 3) the wind climate and topographical data have a built-in uncertainty that, however, is more evenly distributed if more locations are included in the analysis.

For each circle's area around a specific mini-grid location, the Global Wind Atlas data for the area are extrapolated to a height of 20 m above ground so that it is more representative of the resource that a small wind turbine would experience. These are then analysed, and the wind speeds of the top 10% of the locations, those with the highest wind speeds, are collected and averaged. Thus, the wind-resource information that is extracted is the average of the top 10% annual mean wind speeds from within the 2.5 km radius circle.

7.1.2 Mini-grid site locations and mini-grid electrical capacities

Locations for the mini-grid sites are taken from the mini-grid site information as shown in Annex 1 of this report. All of the sites with an electrical capacity of 150kW or less have been analysed with the exception of three sites that do not have location information. The 150kW cut-off was chosen to ensure that the project's demonstration turbine has a reasonable power-to-capacity ratio to the mini-grid's capacity, given that the envisaged turbine will have a rated capacity of between 5 and 20kW.

In all there are 57 sites under 150kW, their geographical locations being shown in Figure 9. The operational statuses of these mini-grids are shown in Annex 1.

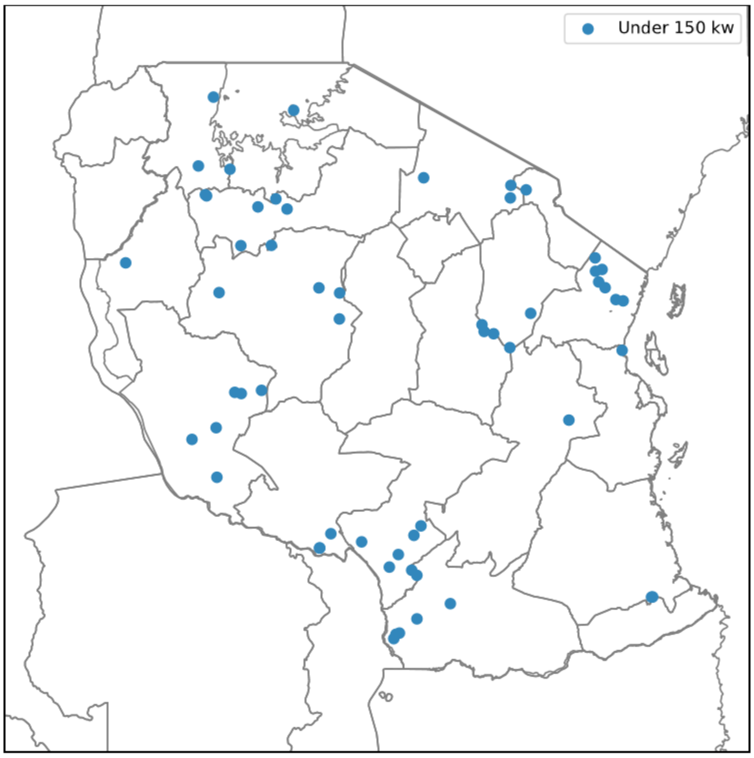

Figure 9. Location of all sites under 150kW

7.2 Classification of mini-grids according to wind potential

The maps below give the locations of the mini-grid sites according to the wind potential calculated by the analysis. An annual average wind speed of 4m/s or above has been chosen as indicating that a site has feasible potential. This, of course, is a very coarse delineator because feasibility depends on a huge range of other factors, including specific wind-turbine performance, exact siting, mini-grid system design, consumption patterns, the economic context, and institutional and community factors, to name just a few. An outline of how the Kenya Miniwind project aims to make a more accurate analysis of feasibility, which includes the value of the wind energy produced, and not just the amount, is given in Section 7.4.

It should be noted that the following maps all give indications of the wind potential in m/s, with the numerical value representing the ***average of the top 10% mean annual wind speeds.***

7.2.1 All sites under 150 kW

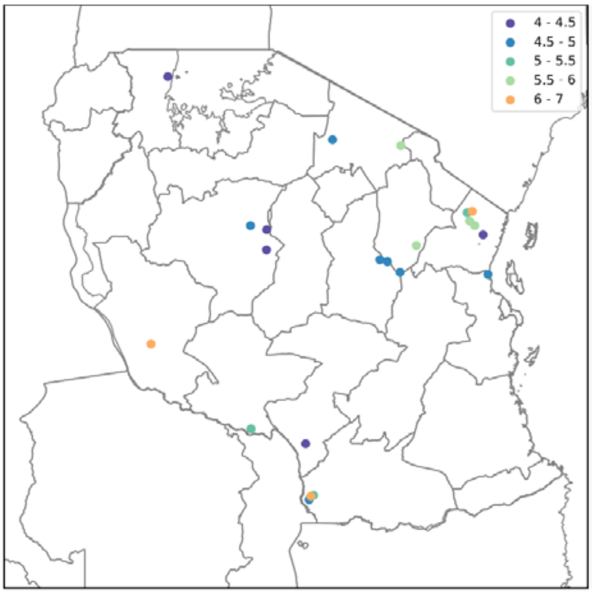

Figure 10. Sites with a wind speed above 4m/s

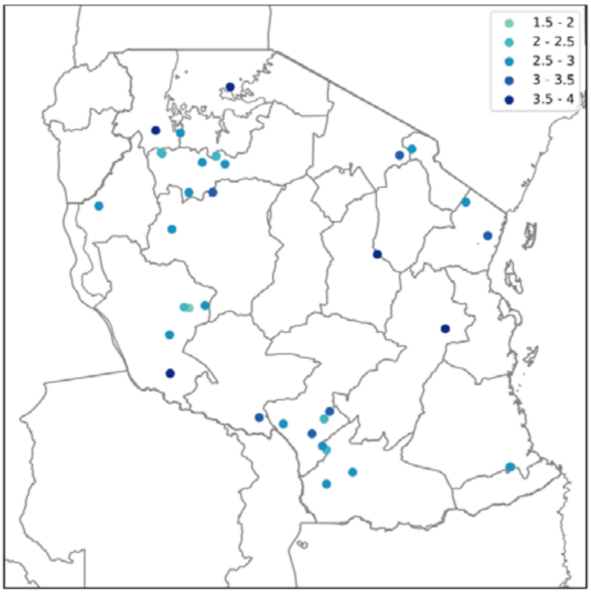

Figure 11. Sites with a wind speed below 4m/s

Of the 57 sites with coordinates, 23 have a wind potential over 4 m/s. In Table 7 these figures are characterized according to wind speed and ownership. It should be noted that there are no TANESCO or government sites in this category.

Wind speed category (m/s)	Community	Mission	Private	Total
4.0-4.5	2	2	1	5
4.5-5.0	5	1	1	7
5.0-5.5	1	3	0	4
5.5-6.0		1	3	4
6.0-6.5			1	1
6.5-7.0		2		2
Total	**8**	**9**	**6**	**23**

Table 7. Wind-speed categories for mini-grids according to ownership.

Table 8 gives the wind-speed categories according to energy source. Note that there are no sites using either fossil fuels or hybrid sources.

Wind speed category (m/s)	Biomass	Hydro	Solar	Total
4.0-4.5	1	2	2	5
4.5-5.0		1	6	7
5.0-5.5		4		4
5.5-6.0	2	2		4
6.0-6.5	1			1
6.5-7.0		2		2
Total	**4**	**11**	**8**	**23**

Table 8. Wind-speed categories for mini-grids according to energy source.

Thus, from the data set of available mini-grids, it is estimated that approximately 23 of the total of 57 (40%) are potentially suitable for the integration of wind power when considering the wind resource alone.

7.4 Further investigation of the feasibility of wind power

As part of Activity 2.1 (Feasibility Studies), a more detailed assessment will be made of the feasibility of the integration of wind power by carrying out preliminary feasibility studies on five test sites. These studies will include an assessment of the wind resource and will also cover the range of other aspects necessary when considering introducing a wind turbine into a community with an existing mini-grid. In combination with this, Activities 4.2 (Demonstration of integration) and 4.6 (Performance of hybrid mini-grid operation) will investigate the *value* of the wind energy produced, rather than the straightforward price of each kWh generated. Much of the economic feasibility of integrating wind power into a mini-grid will depend on the correlation between the temporal profile of wind-power production, solar-power production and consumer consumption.

7.4.1 Outline of methods used in investigating the value of wind power

Conventional mini-grids based on solar PV for generation require a certain amount of battery storage capacity, first, to handle fluctuating loads, and secondly, to be able to provide consumers with energy when the sun is no longer shining. It is frequently during the hours of darkness that much of the load on such mini-grids is present, as power is required for electric lighting. The drawback of battery storage (most commonly still using lead-acid technology) is that it is costly to purchase and will need regular replacement throughout the life of the mini-grid. However, if a community being served by an existing mini-grid requires more electrical energy than it currently obtains, there is little choice but to expand the solar PV capacity and, along with it, the battery storage capacity, incurring the extra costs involved.

If wind energy is now added by integrating a wind turbine into the mini-grid system, then the value of the energy produced will depend on the daily profile of the wind resource. If the energy produced from wind has a similar profile to that from solar PV, then the competitiveness of the wind energy will be on a purely cost of energy produced basis because a similar amount of battery storage will still need to be added.

However, if the wind frequently blows during the hours of dusk and overnight, which is a common phenomenon, then, in the opinion of this project, it can be introduced into the system *without* having to expand the battery-storage capacity. This represents a significant saving in capital expenditure and running expenses and thus an increase in the value of wind energy.

To assess the economic benefit of integrating wind power as opposed to adding solar power, this project will carry out a number of simulations of mini-grid scenarios as outlined above. These will, in the first instance, use generic data, but the simulations will be refined as data is collected from the demonstration turbine and its associated mini-grid.

8. Summary and conclusions

The Government of Tanzania has made considerable progress in recent years in encouraging the private sector to become involved in the development of mini-grids, as well as promoting the use sources of renewable energy in general. As a result, its current legislation takes into account differences in the costs of various technologies and assigns tariff levels accordingly. Moreover, licensing and registration requirements have been simplified. Nevertheless, the tariff that mini-grids charge is still significantly higher than the cross-subsidized retail tariff charged by the national utility, and the planning process for new mini-grids remains long and complicated.

Currently there are at least 110 existing mini-grids in Tanzania. Of these, 60 have an installed capacity below 150 kW. And of these, geographical coordinates are available for 57 sites, of which 23 have a wind potential above 4 m/s.

According to forecasts, more than 3,400 settlements will not be reached by the grid by 2022 and will therefore be left as potential candidates for mini-grid electrification. Specific plans for electrification by mini-grids have been devised for 154 so-called development centres. Unfortunately coordinates have not been available for these sites, and it has therefore not been possible to assess the wind potential.

There are currently more than seven private companies in Tanzania engaged in deploying mini-grids that incorporate renewable energy, but none of them have mini-grids as their core business. Likewise, there are currently almost no small-scale wind-turbine manufacturing activities in Tanzania, although there are several years of experience in using wind turbines for water pumping.

8.1 Policy framework for rural electrification

In recent years, the Government of Tanzania has started recognizing the role of the private sector in increasing and diversifying the country's energy supply, including the development of renewable energy-based mini-grids. Rural electrification has been a political priority since the first National Energy Policy in 1992, but it was not until its revision in 2003 that the sector was liberalized and the private sector was encouraged to invest in the deployment of mini-grids. Under the Rural Energy Act of 2005, a Rural Energy Agency (REA) was established to mobilize resources for rural electrification. Later, in 2008, the first Small Power Producers (SPP) framework was adopted with the purpose of accelerating the development of renewable energy-based mini-grids. The first version encouraged low-cost investment in mini-grids and outlined a clear process for initiation and licensing. It also included Standardized Power Purchase Agreements (SPPA) and technology-neutral Standardized Power Purchase Tariffs for renewable energy in mini-grids. The tariffs received could vary depending on whether the off-taker was the national utility TANESCO or a retail customer.

In 2015, the first-generation SPP framework was revised in order to encourage greater private-sector involvement and to support mini-grids that incorporated solar and wind. With the revision, the feed-in-tariff now became the same, regardless of the off-taker. Furthermore, the framework was no longer technology-neutral and would instead take into account differences in the costs of various technologies. Thus, renewable energy feed-in tariffs determined by EWURA would be applied to renewable energy projects between 0.1-1 MW, while projects with a capacity between 1-10 MW would be awarded through a competitive bidding process. For Very Small Power Producers with a capacity of less than 100 kW, the second-generation SPP framework gives them exemption from licensing and tariff regulation requirements. The third and most recent revision of the SPP framework in 2017 made further progress in providing guidance for mini-grids for when the national grid arrives and in simplifying the licensing and registration requirements.

Overall, the regulatory framework for renewable energy-based mini-grids in Tanzania has seen decisive progress over the past years and has reached a stage where it is far easier for private-sector companies to become engaged in developing renewable energy-based mini-grids. However, challenges remain. One of the most significant is that, although the feed-in tariffs charged by mini-grids are approved by EWURA, they still do not fully reflect the true costs and are significantly higher than TANESCO's cross-subsidized retail tariffs. Furthermore, the planning process for new mini-grids remains long and complicated, and there is a general lack of information on aspects such as energy resources, funding sources and results from operational mini-grids.

8.2 Current and planned mini-grids

The motivation for establishing mini-grids in Tanzania is significant, as it has been estimated that this is the most cost-effective means for supplying roughly half of the population, rather than making grid extensions. The latest update as of April 2017 indicates that there are currently 110 mini-grids serving 185,000 customers in operation in Tanzania, 94 of which are isolated mini-grids not connected to the grid.

The oldest and largest of these are owned and operated by TANESCO and use fossil fuels and hydropower. Missions have also established mini-grids for many years, mainly exploiting small-scale hydro-power. Since 2010, a large number of community and privately owned mini-grids have been established and account for 50% of the mini-grids in Tanzania today. Community and privately owned mini-grids mainly exploiting solar and biomass in the form of Jatropha oil.

The Government of Tanzania, through its National Rural Electrification Program (NREP) for the period 2013-2022, aims to increase the national level of electrification from its current level of 36%. The NREP is currently being updated and consolidated in the form of a Rural Electrification Master Plan (REMP), which is planned to be finalized by September 2018. According to the consultants working on the REMP, finalization will most likely be delayed.

According to the NREP, more than 3,400 settlements will not be reached by the grid by 2022 and will therefore be left as potential candidates for mini-grid electrification. While specific plans are underway, these sites (< 100 kW) can be electrified without licence by mini-grid developers. More specific plans for electrification by mini-grids have been devised for a large number of so-called 'development centres'. While many of these are planned to be reached by the grid expansion programmes, specific plans for mini-grids have been drawn up for 154 centres that are not expected to obtain a grid connection until 2020. In fact this date is likely to be postponed, which makes these centres relevant for the integration of wind turbines for a longer period of time. Unfortunately, UTM coordinates are not available for these sites, and it has therefore not been possible to assess their wind potential.

8.3 Mini-grids with a wind potential above 4 m/s

For the purposes of assessing wind resources in the vicinity of relevant mini-grid sites, it was decided to focus mainly on sites with a capacity below 150 kW because this is an appropriate capacity range for a turbine of the size of 5-20 kW, i.e. that which will be developed for this project. Furthermore, an annual average wind speed of 4 m/s was set as the limit above which sites would be included as having a feasible potential. Of the 57 sites for which we have coordinates with a capacity below 150 kW, 23 have a wind potential above 4 m/s. The distribution of wind speed for these sites according to ownership is shown in Table 9.

Wind speed category (m/s)	Community	Mission	Private	Total
4.0-4.5	2	2	1	5
4.5-5.0	5	1	1	7
5.0-5.5	1	3	0	4
5.5-6.0		1	3	4
6.0-6.5			1	1
6.5-7.0		2		2
Total	**8**	**9**	**6**	**23**

Table 9. Wind-speed categories for mini-grids according to ownership.

8.4 The importation, production and installation of wind turbines in Tanzania

Seven private companies have been identified as being active in the development of mini-grids incorporating renewable energy in Tanzania. Two of them are Powerhive and PowerGen, which are also active in Kenya and have been described in the report for Kenya. The other prominent private-sector players identified include REDAVIA, ENSOL Tanzania Ltd., JUMEME, Rafiki Power and PowerCorner. Many of these private companies are supported by various kinds of national, international and multi-stakeholder donors.

The extent of small-scale wind turbines for electricity generation in Tanzania is currently very limited, though the use of off-grid wind turbines for water pumping is more prevalent, with several hundreds of these small-scale turbines having been installed across the country. This is partly due to the support that wind pumps have received from the government since 1980. Suppliers of off-grid wind turbines are still fighting to stay alive in the market, since companies commonly dissolve within a few years of being established. However, wind turbines are generally available on demand from the major solar suppliers. Two Tanzanian companies involved with wind turbines are Technosys Ltd. and DOBEA Energy Ltd.

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Annex 1.List of existing mini-grids in Tanzania

No	Plant name	Coordinates		Additional Information	Village	District	Region	Year commissioned	Inst. Capa [kW]	Customers (villages)		Connected to	Remarks	Ownership	Average annual wind speed (m/s)
		Eastings	Northings												
1	**Mtwara-Lindi**	40.181	-10.281	Gas	Mtwara Town	Mtwara	Mtwara & Lindi	1969	17,750.0	45439	fossil		Operational	TANESCO	
2	**Songea**	35.648	-10.679	Diesel	Songea	Songea	Ruvuma	1974	8,200.0	28134	fossil		Operational	TANESCO	
3	**Nyumba ya Mungu**	37.467	-3.817	Pangani	Nyumba ya Mungu	Mwanga	Kilimanjaro	1968	8,000.0		hydro	National grid	Operating	TANESCO	
4	**Somanga-Kilwa**	39.296	-8.389	Gas	Somanga	Rufiji	Coast & Lindi	2008	7,500.0	45439	fossil		Operational	TANESCO	
5	**Kigoma-Ujiji**	29.637	-4.877	Diesel	Kigoma	Kigoma	Kigoma	1956	6,000.0	24665	fossil		Operational	TANESCO	
6	**Sumbawanga**	31.623	-7.952	Diesel	Sumbawanga	Sumbawanga	Rukwa	1980	5,000.0	19062	fossil		Operational	TANESCO	
7	**Loliondo**	35.617	-2.051	Diesel	Loliondo	Loliondo	Arusha	2012	5,000.0		fossil		Operational	TANESCO	
8	**Masasi**	38.805	-10.732	Diesel	Masasi	Masasi	Mtwara	1985	4,500.0	45439	fossil		Operational	TANESCO	
9	**Kasulu**	30.107	-4.575	Diesel	Kasulu	Kasulu	Kigoma	2012	2,500.0	24665	fossil		Operational	TANESCO	
10	**Kibondo**	30.723	-3.587	Diesel	Kibondo	Kibondo	Kigoma	2012	2,500.0	24665	fossil		Operational	TANESCO	
11	**Mbinga**	34.997	-10.95	Diesel	Mbinga	Mbinga	Ruvuma	2011	2,500.0	28134	fossil		Operational	TANESCO	
12	**Bukoba**	31.813	-1.331	Diesel	Bukoba	Bukoba	Kagera	1961	2,000.0	52765	fossil		Operational	TANESCO	
13	**Mpanda**	31.073	-6.343	Diesel	Mpanda	Mpanda	Katavi	1995	2,000.0	19062	fossil		Operational	TANESCO	
14	**Tunduru**	37.335	-11.042	Diesel	Tunduru	Tunduru	Ruvuma	2010	2,000.0	28134	fossil		Operational	TANESCO	
15	**Ludewa**	34.692	-10.107	Diesel	Ludewa	Ludewa	Njombe	2012	1,250.0		fossil		Operational	TANESCO	
16	**Tosamaganaga**	35.589	-7.836	Little Ruaha	Tosamaganga	Mafinga	Iringa	1951/1958	1,220.0		hydro	National grid	Non operating	TANESCO	
17	**Kikuletwa**	37.201	-3.427	Kikuletwa + Kware	Kikuletwa	Hai	Kilimanjaro	1937/1950	1,160.0		hydro	National grid	Non operating	TANESCO	
18	**Biharamulo**	31.311	-2.637	Diesel	Biharamulo	Biharamulo	Kagera	2013	1,000.0	52765	fossil		Operational	TANESCO	
19	**Ngara**	30.655	-2.51	Diesel	Ngara	Ngara	Kagera	2013	1,000.0	52765	fossil		Operational	TANESCO	
20	**Mafia**	39.768	-7.855	Diesel	Mafia	Mafia	Coast	1971	900.0		fossil		Operational	TANESCO	
21	**Uwemba - TANESCO**	34.789	-9.466	Hagafiro/Ruhudji	Uwemba	Njombe	Njombe	1991	840.0		hydro	National grid	Operating	TANESCO	
22	**Liwale**	37.924	-9.802	Diesel	Liwale Town	Liwale	Lindi	1975	800.0	45439	fossil		Operational	TANESCO	
23	**Mbalizi**	33.356	-8.932	Nzovwe/Mbalizi	Mbeya	Mbeya	Mbeya	1958	336.0		hydro	National grid	Non operating	TANESCO	
24	**Namtumbo**	36.138	-10.464	Diesel	Namtumbo	Namtumbo	Ruvuma	2011	300.0	28134	fossil		Operational	TANESCO	
25	**TPC**	37.332	-3.533	Steam turbine, cogeneration	Arusha Chini	Moshi	Kilimanjaro	2012/1931	17,500.0		biomass	National grid	Operational	Private	
26	**Kilombero**	36.441	-8.234	Steam turbine, cogeneration	Kilombero	Kilosa	Morogoro	1963/2010	10,500.0		biomass	National grid	Operational	Private	
27	**Mufindi Paper Mill**	35.291	-8.728	Steam turbine, cogeneration	Mufindi Paper Mill	Mufindi	Iringa	1984	9,000.0		biomass	National grid	Operational	Private	
28	**Kagera Sugar**	31.271	-1.218	Steam turbine, cogeneration	Kagera Sugar Mill		Kagera	<1961/1982	5,000.0		biomass	Mini-grid	Operational	Private	
29	**Mwenga**	35.413	-8.485	Little Ruaha	Ifupira	Mufindi	Iringa	2013	4,000.0	1602 (17)	hydro	National grid	Operating	Private	
30	**Mtibwa**	37.639	-6.138	Steam turbine, cogeneration	Turiani	Mvomera	Morogoro	< 1961/1973	4,000.0		biomass	National grid	Operational	Private	
31	**TANWATT**	34.781	-9.288	Steam turbine, cogeneration	Kibena Njombe	Njombe	Njombe	1957/ 1995	2,500.0		biomass	National grid	Operational	Private	
32	**Maguta/Lung'ali (I&II)**	36.194	-7.669			Kilolo	Iringa	2015	2,400.0		hydro	Grid		Private	
33	**Sao Hill**	35.212	-8.398	Steam turbine	Sao Hill Saw Mill	Mufindi	Iringa	1988	1,500.0		biomass	National grid	Operational	Private	
34	**Ngombeni**	39.694	-7.898	Steam turbine	Ngombeni	Mafia	Coast	2014	1,400.0		biomass	Mini-grid	Operational	Private	
35	**Uvinza Mine**	30.387	-5.114	Malagarasi		Uvinza	Kigoma		600.0		hydro	Mini-grid		Private	

No	Plant name	Coordinates Eastings	Northings	Additional Information	Village	District	Region	Year commissioned	Inst. Capa [kW]	Customers (villages)		Connected to	Remarks	Ownership	Average annual wind speed (m/s)
36	**Kitandazi I AHEPO**	35.074	-11.021	Mbinga	Mbangomao	Mbinga	Ruvuma	2015	500.0	842 (3)	hydro	Mini-grid	1 unit Operating	Private	
37	**Mkonge**	38.796	-5.179	Biogass	Muheza Sisal Mill	Muheza	Tanga	2014	150.0		biomass	National grid	Operational	Private	3.4
38	**Masigira - Mahanje**	35.196	-9.956	Masigira/Ruhuhu	Ndolera Tea Estate	Ludewa	Njombe		80.0		hydro	Mini-grid	Operating	Private	2.4
39	**Ukara**	33.045	-1.837	Diesel (30kW) / Solar PV (60kW)	Ukara Island	Ukerewe	Mwanza	2015	60.0		hybrid	Mini-grid		Private	3.5
40				Gasifier (25kW) / Solar PV (21kW)			Mbeya		46.0		hybrid	Mini-grid		Private	-
41	**Kongwa Village**	37.849	-7.261	Gasification	Kongwa	Mororgoro	Morogoro	2016	32.0		biomass	Mini-grid	Operational	Private	3.5
42	**Nyakagomba**	31.933	-2.872	MFP (8.8kW) / Gasifier (32kW)	Nyakagomba	Geita	Geita	2015	32.0		hybrid	Mini-grid		Private	2.7
43					Masumba		Tanga		20.0		solar	Mini-grid	Operational	Private	-
44	**Nyangao**	39.291	-10.333	Lukuledi ??	Nyangao	Ruwangwa	Lindi	2010	15.8		hydro	Mini-grid		Private	2.7
45	**Makumira**	36.827	-3.375			Arumeru	Arusha	2011	10.0		hydro	Mini-grid		Private	3.1
46	**Ngarenanyuki**	36.836	-3.155			Arumeru	Arusha	2011	10.0		hydro	Mini-grid		Private	5.7
47	**Chambo**	32.656	-4.207	MFP SVO/diesel	Chambo	Kahama	Shinyanga	2013	8.8	68	biomass	Mini-Grid	Operational	Private	3.4
48	**Segese**	32.421	-3.533	MFP SVO/diesel	Segese	Kahama	Shinyanga	2014	8.8	29	biomass	Mini-Grid	Operational	Private	3.0
49	**Kijungu**	37.182	-5.397	MFP SVO/diesel	Kijungu	Kiteto	Manyara	2014	8.8	10	biomass	Mini-Grid	Operational	Private	5.6
50	**Kona Nne**	31.743	-5.034	MFP SVO/diesel	Kona Nne	Kaliua	Tabora	2014	8.8	14	biomass	Mini-Grid	Operational	Private	2.8
51	**Ulowa**	32.123	-4.212	MFP SVO/diesel	Ulowa No. 5	Kahama	Shinyanga	2013	8.8	85	biomass	Mini-Grid	Operational	Private	2.8
52	**Runazi**	31.382	-2.815	MFP SVO/diesel	Runazi	Biharamulo	Kagera	2014	8.8	69	biomass	Mini-Grid	Operational	private	3.5
53	**Mashewa**	38.669	-5.156	MFP SVO/diesel	Mashewa	Muheza	Tanga	2013	8.8	12	biomass	Mini-Grid	Operational	private	4.2
54	**Kimbo**	38.482	-4.948	MFP SVO/diesel	Kimbo	Muheza	Tanga	2013	8.8	23	biomass	Mini-Grid	Operational	private	5.9
55	**Mlola**	38.428	-4.629	MFP SVO/diesel	Mlola Lwandai	Lushoto	Tanga	2013	8.8	40	biomass	Mini-Grid	Operational	private	6.0
56	**Mnazi**	38.307	-4.426	MFP SVO/diesel	Mnazi	Lushoto	Tanga	2013	8.8	12	biomass	Mini-Grid	Operational	private	2.6
57	**Lyabukande**	32.93	-3.57	MFP SVO/diesel	Lyabukande	Shinyanga	Shinyanga	2014	8.8	36	biomass	Mini-Grid	Operational	private	2.8
58	**Mwakitolyo**	32.735	-3.393	MFP SVO/diesel	Mwakitolyo	Shinyanga	Shinyanga	2014	8.8	38	biomass	Mini-Grid	Operational	private	2.4
59	**Runzewe**	31.525	-3.339	MFP SVO/diesel	Runzewe	Bukombe	Geita	2013	8.8	65	biomass	Mini-Grid	Operational	private	2.5
60	**Uyovu**	31.503	-3.319	MFP SVO/diesel	Uyovu	Bukombe	Geita	2014	8.8	25	biomass	Mini-Grid	Operational	private	2.5
61		38.778	-6.044		Devergy	Bagamoyo	Coast		2.0	100	solar	Mini-grid	Operational	Private	4.5
62	**Tulila - Chipole**	35.271	-10.805	Ruvuma	Chipole Mission	Songea	Ruvuma	2016	5,000.0		hydro	Mini-grid	Operating	Mission	
63	**Yovi Phase I**	36.804	-7.568	Msolwa		Mikumi	Morogoro	2015	900.0		hydro	Mini-grid		Mission	
64	**Peramiho - Likingo**	35.446	-10.427	Luhira & Mkingazi	Peramiho Mission	Songea	Ruvuma	1962/86	542.0		hydro	Mini-grid	Operating	Mission	
65	**Lupilo - Chipole**	35.201	-10.863	Ruvuma	Chipole Mission	Songea	Ruvuma	2006	400.0		hydro	Mini-grid	Operating	Mission	
66	**Ndanda**	39.026	-10.502	Ndanda	Ndanda Mission	Masasi	Mtwara	1986	310.0		hydro	Mini-grid	Operating	Mission	
67	**Uwemba - Mission**	34.789	-9.458	Hagafiro/Ruhudji	Uwemba	Njombe	N jombe	1971/1988	200.0	-1	hydro	Mini grid	Operating	Mission	
68	**Imiliwaha**	34.63	-9.593	Lupali/Ruhuhu	Imiliwaha Sisters Co	Njombe	Njombe	1980	180.0		hydro	Mini-grid	Operating	Mission	
69	**Bulongwa**	34.039	-9.324	Bulongwa	Bulongwa Mission	Makete	Njombe		180.0		hydro	Mini-grid		Mission	
70	**Kipengele**	34.431	-9.301	Mbarali	Kipengele	Makete	Njombe	2012	180.0		hydro	Mini-grid	Operating	Mission	
71	**Lugarawa**	34.715	-9.814	Lugarawa/Ruhuhu	Lugarawa	Ludewa	Njombe	1979/2015	140.0		hydro	Mini-grid	Operating	Mission	4.0
72	**Mavanga**	35.105	-9.868	Mlomboji/Ruhuhu	Mavanga	Ludewa	Njombe	2002	120.0		hydro	Mini-grid	Operating	Mission	2.7
73	**Mamba**	31.692	-7.394	Mamba/Kavuvu	Mamba	Mlele	Katavi	1932	100.0		hydro	Mini-grid	Operating	Mission	2.8

* Annual average wind speed = the average of the top 10% annual mean wind speeds at 20 m height, from within a 2.5 km radius circle of the mini-grid location.

No	Plant name	Coordinates		Additional Information	Village	District	Region	Year commissioned	Inst. Capa [kW]	Customers (villages)		Connected to	Remarks	Ownership	Average annual wind speed (m/s)
		Eastings	Northings												
74	Kabanga	30.113	-4.513			Kasulu	Kigoma		90.0		hydro	Mini-grid		Mission	2.7
75	**Ndorage**	31.645	-1.606		Ndorage Mission		Kagera	1961	55.0		hydro	Mini-grid		Mission	4.0
76	**Kindimba**	34.891	-10.954	Mangaka	Kindimba	Mbinga	Ruvuma		50.0		hydro	Mini-grid	Operating	Mission	5.5
77	**Kaengesa**	31.705	-8.256	Kaengesa/Momba	Kaengesa Mission	Sumbawanga	Rukwa	1967	44.0		hydro	Mini-grid	Operating	Mission	3.8
78	**Hanga**	35.78	-10.446	Ruvuma	Hanga Mission	Namtumbo	Ruvuma		40.0		hydro	Mini-grid		Mission	2.6
79	**Litembo**	34.83	-10.975	Ndumbi-	Litembo Mission	Mbinga	Ruvuma	1982	40.0		hydro	Mini-grid	Operating	Mission	6.6
80	**Ikonda**	34.231	-9.377		Tandala	Makete	Njombe	1975	40.0		hydro	Mini-grid	Operating	Mission	2.8
81	Uliwa	34.872	-9.597		Uliwa Mission	Njombe	Njombe	1992	40.0		hydro	Mini-grid		Mission	3.5
82	**Nyangao**	39.311	-10.33	Lukuledi ??	Nyangao	Ruwangwa	Lindi	1974	38.8		hydro	Mini-grid		Mission	2.1
83	Chala	31.27	-7.597	Mfuisi/Kavuvu	Chala	Nkasi	Rukwa		30.0		hydro	Mini-grid	Operating	Mission	6.7
84	**Rungwe**	33.694	-9.236			Rungwe	Mbeya	1964	21.2		hydro	Mini-grid		Mission	3.4
85	**Isoko**	33.498	-9.481	Isoko/Songwe	Isoko	Ileje	Mbeya	1973	15.5		hydro	Mini-grid	Operating	Mission	5.2
86	**Mvimwa**				near Kate	Nkasi	Rukwa	1990-99?	14.0		hydro	Mini-grid		Mission	-
87	**Isoko**	33.498	-9.485	Isoko/Songwe	Isoko	Ileje	Mbeya	1973	7.3		hydro	Mini-grid	Operating	Mission	5.2
88	**Sakare Soni**	38.369	-4.848			Lushoto	Tanga	1948	6.3		hydro	Mini-grid		Mission	5.7
89	**Maguu**	34.792	-11.05		Maguu Mission	Mbinga	Ruvuma	1988	4.0		hydro	Mini-grid		Mission	4.5
90	**Mbarali**	34.317	-8.676	Mbarali	Mbarali	Mbarali	Mbeya	1972	700.0		hydro	Mini-grid	Operating	Government	
91	**Mngeta**	36.129	-8.318	Kilombero??	Mngeta/Chita??	Ifakara	Morogoro		600.0		hydro	Mini-grid	Operating	Government	
92	**Kitai**	35.197	-10.709	Likoyu	Kitai Prison	Songea	Ruvuma	1976	45.0		hydro	Mini-grid	Operating	Governmen	2.5
93	**Ikondo II**	35.267	-9.11	Kyepa/Mnyera	Ikondo	Njombe	Njombe	2015	347.0	180	hydro	National grid	Operating?	Community	
94	**Mawengi (Lumama)**	34.485	-9.853	Kisongo/Ruhuhu	Mawengi	Ludewa	Njombe	2009/2012	300.0	1512 (8)	hydro	Mini-grid	Operating	Community	
95	**Bomalang'ombe**	37.137	-3.336	Lukosi	Bomalang'ombe	Kilolo	Iringa	2001	250.0	331	hydro	Mini-grid	Operating	Community	
96	**Matembwe**	35.144	-9.264	Mnyera	Matembwe	Njombe	Njombe	1984	120.0	624	hydro	National grid 2	Operating	Community	2.4
97	**Ikondo I**	35.267	-9.1	Kyepa/Mnyera	Ikondo	Njombe	Njombe	2004	83.0	177	hydro	National grid	Operating?	Community	3.0
98		33.843	-5.495		Tura	Uyui	Tabora	2015	30.0	1053	solar	Mini-grid	Operational	Community	4.4
99		33.847	-5.041		Loya	Uyui	Tabora	2015	30.0	1053	solar	Mini-grid	Operational	Community	4.1
100		32.017	-6.777		Nsenkwa	Mlele	Katavi	2015	30.0	1053	solar	Mini-grid	Operational	Community	2.4
101		32.484	-6.742		Ilunde	Mlele	Katavi	2015	30.0	1053	solar	Mini-grid	Operational	Community	2.5
102		36.369	-5.714		Leganga	Kongwa	Dodoma	2015	15.0	1053	solar	Mini-grid	Operational	Community	4.5
103		36.332	-5.596		Ngutoto	Kongwa	Dodoma	2015	15.0	1053	solar	Mini-grid	Operational	Community	3.7
104		36.818	-5.996		Lobilo	Kongwa	Dodoma	2015	15.0	1053	solar	Mini-grid	Operational	Community	4.8
105		36.536	-5.754		Silale	Kongwa	Dodoma	2015	15.0	1053	solar	Mini-grid	Operational	Community	4.6
106		33.486	-4.951		Lutende	Uyui	Tabora	2015	15.0	1053	solar	Mini-grid	Operational	Community	4.5
107		32.13	-6.798		Mapili	Mlele	Katavi	2015	15.0	1053	solar	Mini-grid	Operational	Community	1.9
108	**Kinko**	38.313	-4.66	Kinko		Lushoto	Tanga	2006	10.0	100	hydro	Mini-grid	Operating	Community	5.5
109	**Mji Mwema**	37.103	-3.234	MFP SVO/diesel	Matadi	Siha	Kilimanjaro	2013	8.8	35	biomass	Mini-Grid	Operational	Community	2.8
110		35.314	-3.022		Maasai Village	Monduli	Arusha		2.0		solar	Mini-grid	Operational	Community	5.0

* Annual average wind speed = the average of the top 10% annual mean wind speeds at 20m height, from within a 2.5km radius circle of the mini-grid location

Data source: https://energydata.info/dataset/mini-grid-locations-in-tanzania